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On-Farm Water Management Study

An evaluation of on-farm
water management options in Alberta

Summary Report

Alberta

On-Farm Water Management Study

An Evaluation of On-Farm Water Management Options in Alberta

Volume I: Summary Report

Prepared by
Alberta Agriculture, Food and Rural Development
Alberta Environmental Protection
Alberta Municipal Affairs

in association with
W-E-R Engineering Ltd.

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On-Farm Water Management Study
Executive Summary

Background

The most common form of farmland drainage in Alberta has been uncontrolled drainage. Uncontrolled drainage is defined as drainage by field ditches without any measures to temporarily or permanently retain the drained water. All forms of drainage result in the loss of wetlands and the benefits they provide, such as wildlife habitat, groundwater recharge, and downstream flood and erosion reduction. Uncontrolled drainage has the most negative environmental effects, and also permanently removes valuable water from the farm.

The need to develop better alternatives to uncontrolled drainage was highlighted by several studies in the 1980s, including *Drainage Potential in Alberta: An Integrated Study* (Alberta Water Resources Commission, 1987). That study recommended that:

> *funding be provided for development and testing of drainage techniques which both reduce downstream impacts and provide for wildlife habitat loss mitigation. These techniques would include controlled or "choked" drainage and [wetland] consolidation.*

In response to this recommendation, the Alberta government departments of Agriculture, Environment, Forestry, Lands and Wildlife, and Municipal Affairs and the Alberta Water Resources Commission established the "On-Farm Water Management Study" on March 17, 1987. The goal of this study was:

> *to identify alternatives to uncontrolled farmland drainage which would meet the needs of producers in the Peace River region and central Alberta, while sustaining the soil, water and wildlife resources.*

Six sites were chosen for case studies to evaluate and demonstrate selected water management alternatives at the small watershed level in the central and Peace River regions of Alberta (Table 1).

TABLE 1. Summary of Research/Demonstration Projects

Site Name/ Location	Water Management Technique	Research/Demonstration Purpose
Arnholtz Site/ Central Alberta	Uncontrolled drainage	Impact of uncontrolled surface drainage on farm operations and peak runoff rates.
Glasier Site/ Peace River region	Choked drainage	Impact of surface drainage with temporary on-farm water storage on farm operations and peak runoff rates.
Sipma Site/ Peace River region	Slough consolidation - agriculture	Impact of surface drainage with on-farm water storage for stock watering on farm operations and peak runoff rates.
Olson Site/ Peace River Region	Slough consolidation - agriculture/waterfowl	Impact of surface and subsurface drainage with on-farm water storage on farm operations, waterfowl and peak runoff rates.
Massey Site/ Central Alberta	Slough consolidation - agriculture/waterfowl	Impact of subsurface drainage with on-farm water storage on farm operations, waterfowl and peak runoff rates.
Bredo Site/ North-Central Alberta	Peatland water management	Impact of draining peatland on runoff rates and volumes, and impact of backflooding of peat soils on moisture content, water table control and soil temperatures.

Data concerning hydrology, agronomy and economics were collected at all six sites. As well, waterfowl-related data were collected for the Olson and Massey projects. The collected data were analyzed to determine the hydrological effectiveness, agronomic benefits, financial and socio-economic viability, and waterfowl impacts of the projects. The following conclusions are based on the results of these analyses.

Major Conclusion

> ***While various alternatives to uncontrolled drainage were found to satisfy one or more resource management objectives, no measures were found that would sustain agriculture and the soil, water and wildlife resources over the long term.***

The controlled water management systems provided some agronomic benefits and protected downstream areas from increased erosion, flooding and sedimentation. However, the systems were not viable financially (i.e., in terms of on-farm costs and benefits) or economically (i.e., in terms of on- and off-farm costs and benefits at a provincial scale) and did not maintain wildlife populations.

Although these systems could be refined to increase the benefits and reduce habitat loss, the improvements would not be sufficient to achieve sustainability on a quarter section basis. That is, the use of controlled rather than uncontrolled drainage will not sustain agriculture and the environment over the long term.

Despite the disadvantages of drainage, agricultural producers will likely continue to want to drain because of the potential agronomic advantages such as reduced crop losses, improved trafficability and timing of field operations, increased acreage under cultivation, increased crop choices and yields, and reduced input costs. Furthermore, most producers will likely prefer uncontrolled drainage because of the low farm costs for construction.

Study Conclusions

1. **The controlled water management alternatives examined in this study were all successful in maintaining near pre-drainage flows.**

   Maintaining pre-drainage flow conditions is essential to avoid off-farm flow increases which could increase downstream erosion, flooding, sedimentation and water quality deterioration, or increase infrastructure costs.

2. **Uncontrolled drainage results in significant increases in off-farm peak flows which can cause serious negative impacts such as erosion, flooding, sedimentation and water quality deterioration, as well as costly remediation.**

3. **Farm water management techniques which include consolidation of temporary wetlands as a means of on-farm water storage can provide needed water for domestic and livestock use.**

   Most of Alberta has a moisture deficit for at least part of the growing season which may limit the water supply for domestic and livestock use. A secure farm water supply is especially critical for reducing the risk of cattle production losses due to drought.

   Although this is a valuable benefit, other water management options would provide this same benefit without requiring wetland drainage. For example, existing permanent wetlands could be deepened or new farm dugouts could be excavated.

4. **The controlled water management alternatives all achieved some agronomic benefits, although the benefits were very small in some cases.**

   The five controlled drainage projects resulted in a net increase in the acreage available for crop production at the sites. Some projects also resulted in such agronomic benefits as improved field efficiency and timing, reduced input costs, increased yields, increased livestock carrying capacity, reduced risk of water shortages, or increased cropping options. The actual benefits were, in some cases, much less than the benefits expected by the cooperating producers. For example, surface ditches remained wet and impeded field operations in some projects.

5. **None of the six projects were viable from a farm financial perspective.**

   The farm financial evaluations, comparing on-farm costs with on-farm benefits, showed that the agronomic benefits were not sufficient to offset the capital, operating and maintenance costs. With no government cost-sharing, benefit/cost ratios ranged from about 0.2 to 0.5. Crop prices used in the analysis were based on 15-year averages (1976/77 to 1990/91), which included some relatively high prices; therefore the low benefit/cost ratios are not primarily the result of the present depressed crop prices.

   Even with the actual government cost-sharing for these projects, which ranged from 55% to over 75% of the total project costs, only the Massey project approached financial viability. Almost no government assistance is now available for such projects.

   Financial viability was also assessed by changing various assumptions: ±20% changes in total annual revenue projections, increased crop yields and/or crop quality in the drained depressions, revised construction costs based on design changes, changes in farm efficiencies, and a lowering of the discount (interest) rate from 10% to 5%. In these tests, only the Massey project came close to the break-even point (assuming that crop yields from the drained depressions were equal to upland crop yields).

   The financial results for the projects reinforce the contention that non-financial factors also influence producers' water management decisions. For many producers, practical factors which make their lands easier to farm, such as field efficiency, trafficability and timing, are key objectives for their water management systems even if these factors are not significant from a financial perspective.

6. **None of the six projects were viable from a socio-economic perspective.**

   The socio-economic assessments, comparing on- and off-farm costs with on- and off-farm benefits, reflect the economic value of the projects to society at a provincial scale. The low benefit/cost ratios reflect the high costs of mitigating on-farm habitat loss and downstream erosion and flooding. Without the control structures used in the five controlled drainage projects, the negative off-farm effects would have been significantly greater.

7. **Slough consolidation with limited waterfowl habitat mitigation resulted in significant losses in wetland habitat and waterfowl productivity. Effective waterfowl habitat will decrease up to 90% if this technique is carried out on large blocks of land.**

   This study tested the effects of consolidation of temporary wetlands combined with waterfowl habitat mitigation of the consolidation pond and very limited upland habitat mitigation. The impact of this technique on waterfowl productivity is strongly negative for the drained quarter. For example, the estimated loss of habitat for the Massey quarter averaged 91% for two representative dabbling duck species (Gadwall and Blue-winged Teal) and 81% for a diving duck species (Canvasback).

   In addition to reducing waterfowl productivity, the loss of wetland habitat will harm many other species of birds, mammals, amphibians, reptiles and plants which depend on wetlands for all or part of their life cycle.

8. **The results from the Massey project highlight the need to resolve conflicting resource management goals and indicate that finding acceptable compromises will not be easy.**

This project showed that slough consolidation using subsurface tubing with Jensen inlets is technically feasible and may be financially viable on knob and kettle topography if crop yields from the drained depressional areas are equal to upland yields. This creates a serious concern because knob and kettle topography provides prime waterfowl habitat due to the many wetlands characteristic of this topography. On one hand, governments and the private sector are working to restore waterfowl populations; on the other hand, greater stability in agriculture, increased demand for a more secure water supply for livestock production, or higher commodity prices could prompt more producers to implement water management systems similar to the Massey project.

The problem of competing land uses needs to be addressed to find a middle ground that will enable Alberta to sustain both environmental resources and agriculture.

Finding a middle ground will be difficult. Although many producers value wildlife, others view it as little more than a nuisance. Furthermore, even those producers willing to actively encourage wildlife may consider wetland consolidation with limited habitat mitigation as a reasonable compromise between the needs of agriculture and wildlife. For wildlife populations, this "compromise" would be very detrimental.

The Challenge

The study's major conclusion points out the challenge facing Albertans of how to guide farm water management practices towards agricultural and environmental sustainability. Meeting this challenge is important in all areas of Alberta and crucial in knob and kettle terrain.

The On-Farm Water Management Study Steering Committee believes we can meet this challenge through two main approaches. Improved goal setting and planning needs to occur at the provincial, municipal/sub-basin, and farm levels. Government resources and programs should support sustainable resource management.

This challenge is one of many we face in creating a sustainable future. We can build such a future by working together and by developing a common goal towards stewardship of our resources.

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1.0 Introduction

1.1 Background to the On-Farm Water Management Study

Farmland drainage has long been considered to be the most effective means of protecting crops from losses due to excess water. Other reasons for drainage include improved timing of field operations, improved trafficability, increased land under cultivation, increased crop production, reduced field operation costs, reduced weed control costs and reduced waterfowl damage to crops.

While the agricultural reasons for draining wetlands were easy to see, the reasons for retaining wetlands were only gradually recognized. In particular, a marked decline in waterfowl populations in the 1980s was attributed in part to the loss of wetland habitat due to farmland drainage. As well, other important functions of wetlands became more widely recognized. These functions include flood and erosion control, water purification, soil moisture recharge, groundwater recharge, and recreational and aesthetic enjoyment. Native grasses and sedges found in and around wetlands are high in protein and can be used as forage for livestock. Permanent wetlands* store water which can be used for farm activities like livestock watering and supplemental irrigation.

In Alberta, the most common form of farmland drainage has been uncontrolled drainage. Uncontrolled drainage is surface drainage by field ditches without any measures to temporarily or permanently retain the drained water. Uncontrolled drainage can be particularly harmful because it not only results in the loss of wetland areas, but also increases downstream flooding and erosion and, consequently, increases expenditures for infrastructure repair and maintenance. Also uncontrolled drainage, especially in the spring, permanently removes valuable water from the farm. This is especially critical on Alberta farmlands because most of the province suffers from insufficient moisture for at least part of the growing season.

Awareness of the disadvantages of uncontrolled drainage increased in the 1980s, particularly in the central and Peace River regions of Alberta, as more lands were drained and as existing drainage projects continued to have negative effects on farmland and the natural environment. The need to develop better farm water management techniques was highlighted by studies such as *Drainage Potential in Alberta: An Integrated Study* (Alberta Water Resources Commission, 1987) and by increasing awareness arising from operational programs such as Alberta Agriculture's Farmland Development and Reclamation Program and Soil Conservation Area Program, and Alberta Environment's Alberta Water Management and Erosion Control Program. In particular, in *Drainage Potential in Alberta* it was recommended that:

> *funding be provided for development and testing of drainage techniques which both reduce downstream impacts and provide for wildlife habitat loss mitigation. These techniques would include controlled or "choked" drainage and [wetland] consolidation. If these techniques prove practical, the government should provide or redirect incentives for their implementation.*

In response to this recommendation, a task force was established to design a program to demonstrate and evaluate integrated water management concepts which would alleviate some of the negative effects of uncontrolled drainage. The task force had representatives from the Alberta government departments of Agriculture, Environment, Forestry, Lands and Wildlife, and Municipal Affairs, and the Alberta Water Resources Commission. The participating agencies approved the study concept and objectives on March 17, 1987. A steering committee was then formed with representation from the same participating agencies. It formalized the objectives, terms of reference, budgets and schedules for a 3.5-year research/demonstration program called the "On-Farm Water Management Study." The program was subsequently extended for one year to fall 1991 to obtain further data.

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*Refer to Appendix A for definitions of permanent wetlands and other terms used in this report.

1.2 Study Goal and Objectives

The goal of the On-Farm Water Management Study was:

> *to identify alternatives to uncontrolled farmland drainage which would meet the needs of producers in the central and Peace River regions of Alberta, while sustaining the soil, water and wildlife resources.*

The objectives established to meet this goal were as follows:

- to provide actual on-farm data for Alberta conditions for use in operational programs and various awareness, technology transfer and promotional efforts and materials in on-farm water management.
- to develop and standardize data on small watershed hydrology used by provincial agencies in planning, design and construction activities; to develop standards for the possible future increase in private sector involvement in the design and implementation of farm water management projects.
- to provide more reliable field data for drainage and water management planning.
- to develop and test drainage techniques which reduce downstream impacts and/or provide for wildlife habitat loss mitigation. These techniques would include controlled or "choked" drainage and on-farm consolidation of drainage water and wetlands.
- to serve as on-farm water management demonstration projects in the Peace River and central Alberta.
- to document and assess the costs and returns of on-farm water management for agricultural producers, including yields, field work efficiencies, crop quality, construction, operating and maintenance costs and changes in farm net returns.
- to identify non-economic, quality of life impacts and off-farm implications related to water management and waterfowl.

1.3 Research/Demonstration Projects

The On-Farm Water Management Study Steering Committee set out the principal requirements for the selection of farm sites as case studies to evaluate and demonstrate various water management alternatives at the small watershed level in the central and Peace River regions of Alberta. The following project types were to be included: uncontrolled drainage; controlled drainage using chokes; slough consolidation for agricultural use; slough consolidation with wildlife habitat loss mitigation; and peatland drainage and development. The sites also had to be suitable for demonstration purposes (e.g., easily accessible to local producers).

Six research/demonstration sites were chosen through searches of Alberta Agriculture files, communication with agricultural service boards and review of proposed on-farm demonstration projects. Site evaluations and negotiations with agencies and landowners were then carried out.

Most of the selected sites had existing water management projects, constructed under the Farmland Development and Reclamation Program and cost-shared with the producer; the two sites for slough consolidation with habitat loss mitigation were Alberta Agriculture research sites. The use of existing sites minimized study costs but also resulted in some sites having less than optimal conditions for research/demonstration purposes.

The water management techniques and objectives for each project are summarized in Table 1.3-1, and the project locations are shown on Figure 1.3-1.

1.4 Study Reports

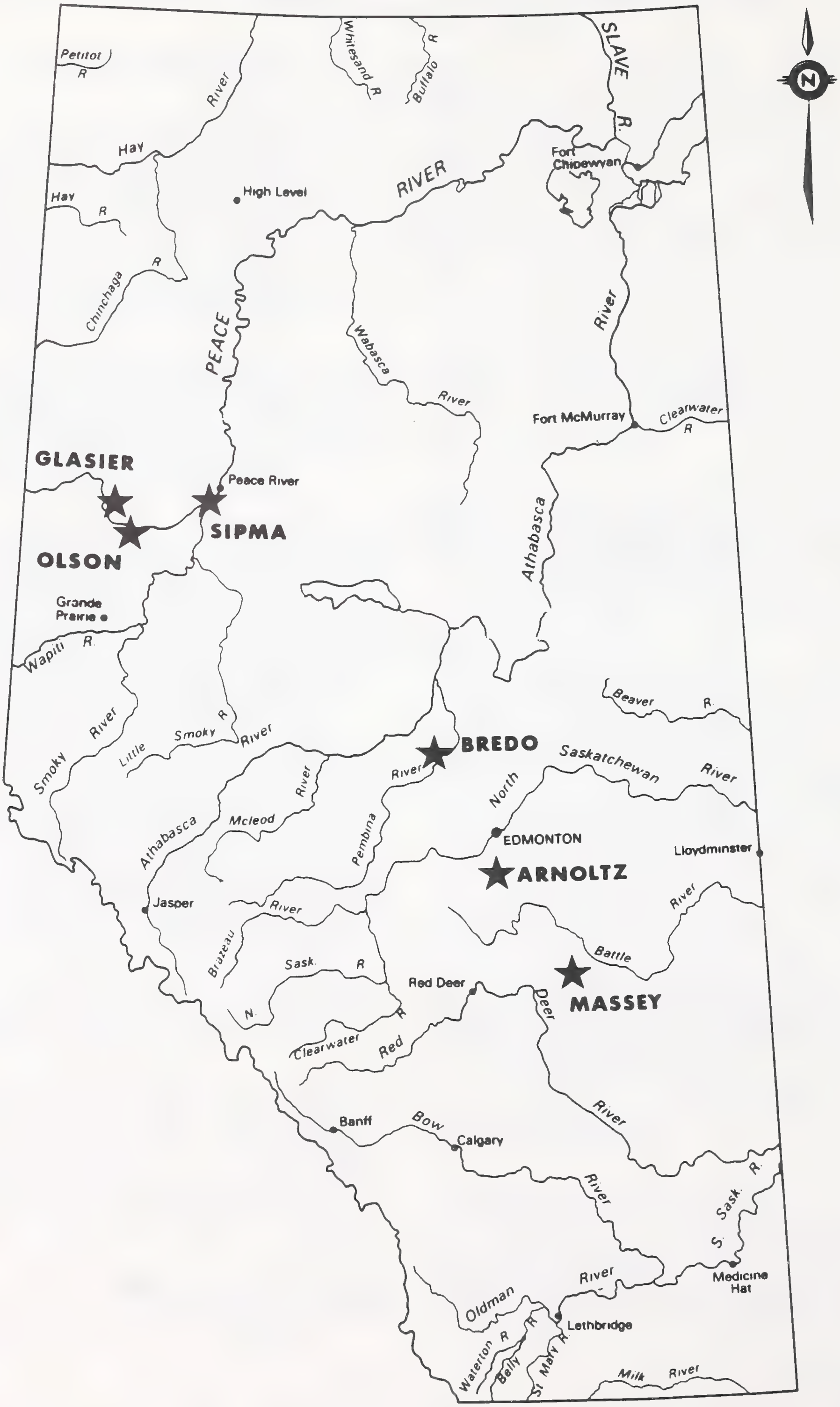
This volume, entitled *Volume I: Summary Report,* is the first of three volumes in the On-Farm Water Management Study. It summarizes the information presented in *Volume II: Research/Demonstration Projects*. Volume II is a technical report which brings together and

TABLE 1.3-1. Summary of Research/Demonstration Projects

Producer	Water Management Technique	Type of Agriculture	Research/Demonstration Purpose
Arnholtz	Uncontrolled drainage	Annual crops	Impact of uncontrolled surface drainage on farm operations and peak runoff rates
Glasier	Choked drainage	Annual crops	Impact of surface drainage with temporary on-farm water storage (for 2 to 4 days) on farm operations and peak runoff rates
Sipma	Slough consolidation - agriculture	Livestock/forage	Impact of surface drainage with on-farm water storage (for stock watering and supplemental irrigation) on farm operations and peak runoff rates
Olson	Slough consolidation - agriculture/waterfowl (Peace River region)	Annual crops	Impact of surface and subsurface drainage with on-farm water storage, on farm operations, waterfowl and peak runoff rates
Massey	Slough consolidation - agriculture/waterfowl (central Alberta)	Annual crops	Impact of subsurface drainage with on-farm water storage, on farm operations, waterfowl and peak runoff rates
Bredo	Peatland water management	Livestock/forage	Impact of draining peatland on runoff rates and volumes, and the effect of peatland backflooding on soil moisture content, water table control and soil temperatures

evaluates the observations and results from the individual reports prepared on the hydrology, agronomy, waterfowl and economics components of the study. These component reports form *Volume III: Component Reports*.

Figure 1.3-1. On-Farm Water Management Project Locations



2.0 Data Collection Methodology

This study investigated farm water management at all six sites from three perspectives: hydrology, agronomy and economics. As well, the Olson and Massey projects were studied from a waterfowl perspective. Details of the data collected and further information on the methodology are available in *Volume II: Research/Demonstration Projects*.

2.1 Meteorologic and Hydrologic Data

Meteorologic Data: Meteorologic stations were set up at each of the six sites to monitor the main meteorologic parameters affecting runoff, water management and use, and crop growth. Monitoring periods varied from two to four years, depending on the site. The data for each site were compiled to create daily and monthly summaries of air temperature, precipitation and relative humidity. Records from the nearest available climatic stations were used to supplement and verify the site data.

Surface Runoff: Surface water runoff for each of the study watersheds was monitored for two to four years as follows: the Arnholtz and Bredo sites, 1989 and 1990; the Glasier and Sipma sites, 1989 to 1991; the Massey site, 1988 to 1990; and the Olson site, 1988 to 1991.

The Arnholtz, Glasier, Sipma and Bredo projects use field ditches to drain depressional wetland areas. Therefore, surface runoff was monitored by measuring ditch flows at strategic locations using flumes with water level recorders. Freeze-thaw conditions at the flumes impaired data collection in 1989 and only approximate estimates of total runoff volumes and peaks were obtained. More intensive manual inspections during the snowmelt periods in 1990 and 1991 significantly improved data reliability.

The Massey project uses subsurface tubing (corrugated plastic pipe) to drain depressional wetland areas, and the drained water is pumped to a consolidation pond. Runoff monitoring for this project consisted of measuring the water volumes pumped to the pond.

The Olson project uses both subsurface tubing and field ditches for drainage, and the drained water is pumped to a consolidation pond. Runoff was monitored by recording volumes pumped to the Olson pond. Ditch outflows were measured with a water level recorder upstream of the outlet weir. Random records of inflows to the site were also collected upstream of the main inflow culvert.

Other: Snowcourse surveys were taken each spring in late February to March to determine total water equivalents of the snowpack. Other hydrologic monitoring consisted of: manual readings of staff and crest gauges located in selected depressions, at ditch controls and in dugouts; mapping ponded areas and estimating storage volumes; mapping of contributing drainage areas during snowmelt and storm events; and photographic documentation of events. To illustrate how conditions during the monitoring period compared with long-term averages, long-term hydrologic data from regionally gauged watersheds were compared to site data.

2.2 Agronomic Data

Soil moisture, soil fertility, crop yields and crop quality were measured and analyzed for the six sites. The length of the data collection period and the number of monitoring locations were limited because of time and budget constraints. The implications of these limitations are discussed in Section 4.3.

Soil Moisture: In 1989, soil moisture was measured using a neutron probe and was monitored approximately monthly over the growing season. In 1990, soil moisture was measured using the gravimetric method. Sampling was carried out four times during the growing season at each site. Soil moisture was not monitored in 1991.

Soil Fertility: Soil fertility samples were collected near the soil moisture monitoring locations using a hand-operated soil auger. In 1989, samples were collected at the Glasier, Olson, Sipma and Bredo sites in the spring, and at the Massey site in the fall. In 1990, samples were collected at all sites in the spring prior to seeding, and in the fall after harvest. Samples from all monitoring locations were analyzed for nitrogen, phosphorus, potassium, sodium, sulphur, soil pH and electrical conductivity. Samples from the peat soils at the Bredo site were also analyzed for zinc, copper, manganese and iron.

Soil Classification: Soils were classified according to *The Canadian System of Soil Classification* (Agriculture Canada, 1978) during soil fertility sampling operations in 1990.

Crop Yields and Quality: Grains were grown at the Arnholtz, Glasier, Olson and Massey sites during the monitoring period. Grain yields were calculated from samples collected near the soil moisture monitoring locations at these four sites in 1989 and 1990. In 1991, only the Olson and Glasier sites were sampled but additional locations were sampled at these two sites. Grain samples were analyzed for protein, phosphorus and moisture content. Producer estimates of grain yields were also recorded.

Mixed grass-legume forages were grown at the Sipma and Bredo sites during the monitoring period. In 1989 and 1990, forage yields were estimated from samples collected near the soil monitoring locations at both sites. In 1991, only the Sipma site was sampled but additional locations were sampled at this site. Forage samples were analyzed for protein, calcium, phosphorus, nitrate and moisture contents.

2.3 Waterfowl Data

Waterfowl were used as the primary indicator of wildlife use of wetlands because of their visibility, relative economic importance and habitat needs closely associated with wetlands. Many other game and non-game species, such as small birds, muskrats, deer and other ungulates, and small mammal predators, also use wetland habitat and are affected by changes in the amount and quality of the habitat. Other wildlife species sighted during the waterfowl surveys were noted.

Waterfowl surveys were conducted at the Massey and Olson sites as described below. The limitations arising from the waterfowl data collection methodology are discussed in Section 4.4.

Study Area Definition: In 1988, the study areas for waterfowl data collection focused on the Massey and Olson consolidation ponds and adjacent quarters. The study areas were expanded for the 1989 and 1990 seasons to encompass a block of nine quarter sections centred on each slough consolidation quarter. These blocks are referred to as the *Massey block* and *Olson block*. A nine-quarter *Comparison block* unaffected by farmland drainage activities was selected for comparison with the Massey block, based on similar topographic, wetland and land use characteristics. It was not possible to establish a comparison block for the Olson project due to drainage activities throughout the region.

Waterfowl Surveys: Waterfowl survey methods were generally similar for the Olson and Massey study areas, with similar timing of surveys, and summarization and analysis of breeding pair and brood data. However, due to the lack of a comparison block for the Olson project and budgetary restrictions, the duration and intensity of surveys differed between the two studies.

Breeding population surveys for both study areas recorded waterfowl location, species, number of birds, sex, social status (e.g., pairs, lone bird) and age class. For the purposes of this study, a breeding population is defined as the number of resident birds in the study area. To calculate the resident breeding population per species, all broods encountered were back-dated to the initiation date of laying for that clutch. *Indicated Breeding Pairs* (IBP) (defined as the estimated number of waterfowl pairs (male and female) that have joined to reproduce) from the survey(s) during or near that period were then used to calculate a mean resident breeding pair population for each species.

Although all broods encountered during the monitoring period were recorded, surveys designed specifically for counting the number of broods were conducted in the same locations as the breeding pair surveys. Brood surveys were conducted for the Olson block in 1988, for both study areas in 1989, and for the Massey quarter and the Comparison block's Central quarter in 1990.

Post-breeding bird surveys were undertaken in the Massey study area in 1988 and 1989, and in the Olson study area in 1988, 1989 and 1990. Survey methods were similar to those for breeding bird and brood surveys.

Other Wildlife Surveys: Sightings of all other birds, mammals and wildlife signs (e.g., tracks, scats) were noted during the waterfowl surveys and other visits to the study areas. Where possible, details were recorded on numbers, sex, age and habitat use.

Wetland Classification: Wetlands were classified for the Massey study only. The classification system was designed by Stewart and Kantrud (1971) for the type of topography in the Massey area. This system recognizes seven classes of wetlands, six of which are found in the Massey study area. The six classes are: ephemeral, temporary, seasonal, semi-permanent, permanent, and alkaline. *Permanent wetlands* are those where water covers the land surface throughout the year in all years. *Semi-permanent wetlands* usually retain water through the growing season. *Seasonal wetlands* contain water for extended periods, especially early in the growing season, but have no water by the end of the growing season. *Temporary* and *ephemeral wetlands* are present for brief periods during the growing season. Extended drought or periods of excess water conditions will change the class of a given wetland.

Habitat Suitability Assessment: Upland land use was classified for the Massey study only. Classification was according to criteria proposed by Ducks Unlimited Canada. Land use was classified by cover types related to nest success rates and attractiveness to nesting waterfowl. Upland land use and wetland areas were mapped based on 1990 field conditions and digitized.

The *Habitat Evaluation Procedure* was used to assess habitat for the Massey block and the Comparison block. In this method, the capability of different habitat types to provide known life requirements for a species (e.g., breeding habitat for Blue-winged Teal) is documented using an index of habitat quality called the *Habitat Suitability Index* (HSI). The HSI is derived from measurements of certain physical characteristics, such as density of wetlands and vegetation height, which describe the suitability of habitat to support the species in question. HSI values range from 0.0 to 1.0 with 1.0 representing optimum conditions for a species and 0.0 representing no suitable habitat. HSI values are multiplied by the area of available habitat to obtain *Habitat Units* (HU).

2.4 Economic Data

The economic data were assessed from two perspectives: farm financial and socio-economic. The *farm financial* evaluation compares on-farm costs with on-farm benefits. The *socio-economic* assessment compares on- and off-farm costs with on- and off-farm benefits, and reflects the economic value of the inputs and output to society at a provincial scale.

The basic methodology used was discounted cash flow analysis (see Gittinger, 1982). The analysis recognizes that future payments must be discounted to their "present value." The method generates three criteria to determine financial or economic feasibility: benefit/cost ratios, net present values and internal rates of return.

For the purposes of this study, these three criteria were defined as follows:

Benefit/Cost ratio (B/C) = Discounted Incremental Net Benefits (DINB) / Discounted Total Investment Costs (DTIC).
Thus the breakeven point occurs when B/C = 1.

Net Present Value (NPV) = DINB - DTIC.
Thus NPV = 0 at the breakeven point and NPV > 0 when the benefits are greater than the costs.

Internal Rate of Return (IRR) is that interest rate where B/C = 1 and NPV = 0.

The basic parameters used in the analysis are listed in Table 2.4-1. The farm financial dis-

TABLE 2.4-1. Basic Parameters Used in Discounted Cash Flow Analysis

	Farm Financial	Socio-Economic
Price Level	constant 1988-92 prices	constant 1988-92 prices
Discount Level	10% per year	5% per year
Time Frame	20 years	30 years

count level of 10% was adopted to be consistent with previous drainage studies in Alberta (Marv Anderson and Associates, 1986 and 1987). A more appropriate rate for 1992 conditions may be somewhere between 5% and 10%. An example of how a 5% value would affect the results is provided in the sensitivity analysis for the Glasier site (see Section 3.2.3). Society is expected to have a longer time frame than a private investor (the producer); the 30-year time frame used here for the socio-economic assessment is a minimum.

The farm financial analysis focused on the direct benefits and costs to the cooperating agricultural producers. The calculations were based on the incremental gross value added from agricultural production if the project is implemented. Incremental income change, that is, the difference between income after the project and income before the project, is the *bottom line*.

The principal net benefit to producers from improved on-farm water management was the additional annual net income from crop and livestock production on the improved agricultural lands plus the auxiliary or efficiency ben-

TABLE 2.4-2. Summary of Auxiliary Agricultural Benefits of Drainage

Benefit	Area Affected	Revenue Increase or Cost Decrease/Acre*	Adjustment Factor**
Improved timing of operations	Total cultivated area	Gross revenue/acre	Timing Factor
Reduced transitional area costs	Transitional area	Seed, fertilizer and chemical costs/acre	--
Improved field pattern efficiencies	Total cultivated area	Total production costs/acre	Efficiency Factor
Improved transitional crop quality	Transitional area	Gross revenue/acre	Trans. Crop Quality Factor
Improved upland crop quality	Upland area	Gross revenue/acre	Upland Crop Quality Factor

* From the principal benefit calculations.

** Estimated as follows:

Timing Factor: 0.25% per non-permanent wetland drained per section to a maximum of 5%.
Efficiency Factor: based on computer simulations via Jensen Engineering Ltd.
Transitional Crop Quality Factor: 10%.
Upland Crop Quality Factor: 0.02% per acre of non-permanent wetlands per section to a maximum of 2%.

efits of farm water management (see Pedology Consultants et al., 1984; Marv Anderson and Associates, 1986 and 1987). The *annual net income* was calculated as: Net Income = Sales - Input Costs - Depreciation. The calculations did not include wages for the producer's labour. The *auxiliary benefits* were identified based in part on a 1990 survey of the six co-operating producers. Table 2.4-2 summarizes how these auxiliary benefits were calculated.

The financial and economic analyses were based on the data collected in the hydrologic, agronomic and waterfowl components of the study as well as data from regional records and Alberta Agriculture census reports. The price data are provided in Appendix A of Volume II. Average crop prices were based on 15-year averages (1976/77 to 1990/91). Crop quality price differentials were based on 10-year averages (1980 to 1989). Crop production costs reflected approximate annual costs for the six sites. Beef prices were based on an 11-year average (1980 to 1990).

The analysis also included estimates of property tax changes resulting from project implementation. For each site, a post-project tax assessment was made with the procedure used for the actual pre-project assessment. Tax assessment changes should not be compared between projects because the changes are based in part on soil quality, which varies between projects, and because Alberta Municipal Affairs was using different assessment methods in different parts of the province at the time that the tax changes were estimated.

3.0 Research/Demonstration Project Results and Evaluation

This chapter describes the six case studies and evaluates them in terms of water management effectiveness, agronomic advantages and disadvantages, and financial and socio-economic viability. Further information on the background, observations, results and evaluations for these six case studies is available in *Volume II: Research/Demonstration Projects*.

3.1 Arnholtz Project — Uncontrolled Drainage

3.1.1 Project Description

Site: The Arnholtz project is located about 13 km south of Leduc and 3 km west of Millet, on the northwest quarter of 25-47-26-W4M. The site is in an agricultural area with grain, forage and livestock production.

The project's principal watershed consists of 16 ha on the south side of the Arnholtz quarter section. During the study, it was found that intermittent runoff also comes from 48 ha in the quarter section south of the Arnholtz site, so the total contributing watershed area is 64 ha.

The 16 ha watershed has a very low slope (about 0.4%). Before drainage, it had 2.65 ha of depressional land consisting of four main sloughs, 3.76 ha of transitional land, and the remainder was upland. For the purposes of this report, *depressional land* is defined as a low-lying area subject to ponding for periods long enough to make it agriculturally unproductive. *Transitional land* is defined as the area between a depression and an upland, occasionally subject to ponding especially during spring snowmelt and high magnitude rainfall events. *Upland* is defined as an agriculturally productive area not subject to ponding.

Objective: to evaluate, at the small watershed level, the effect of uncontrolled drainage on farm operations and on discharge at and beyond the farm boundary.

Water Management System: The project, shown in Figure 3.1-1, was designed to drain the four sloughs on the Arnholtz quarter using low slope, conventional field ditches, called swales. The ditch depths were minimized to allow crossing by farm equipment.

Although this case study was established to evaluate uncontrolled drainage, both Alberta Environment and the County of Wetaskiwin required the overall water management system to use controlled drainage because of downstream flooding concerns in the County of Leduc. Thus the ditches drain into a treed retention area downstream of the 16 ha study watershed. The retention area is in the centre of the quarter section and has a berm and a control culvert at its outlet.

Costs: The project costs for the uncontrolled system (including ditch excavation and grass seeding) totalled $3,000, of which 40% was the producer's share. Operating and maintenance costs are expected to be minimal. (The cost of the retention area is not included here because it is not part of the uncontrolled drainage project.)

Data Collection: Full data collection started in spring 1989 and continued to fall 1990. Agronomic data were collected from three locations: an upland location not affected by the drainage project, with Orthic Dark Gray Chernozemic soils; a drained transition location, with Orthic Humic Gleysolic soils; and an undrained transition location with Orthic Humic Gleysols. The site was seeded to canola in 1989 and oats in 1990. In 1989, only very general yield information, based on swath samples, was obtained because the site was harvested before crop sampling took place.

3.1.2 Water Management System Evaluation

The drainage system was only partially effective. Because of the flat topography on the site and minimal ditch depths, the ditch slopes were flat in many places and ponding occurred along the ditches. As well, the monitoring flume required a drop of 0.15 m to operate effectively. To create this drop, ditch slopes had to be made even lower. In addition, the nearly continuous slow seepage into the Arnholtz quarter from the 48 ha to the south augmented

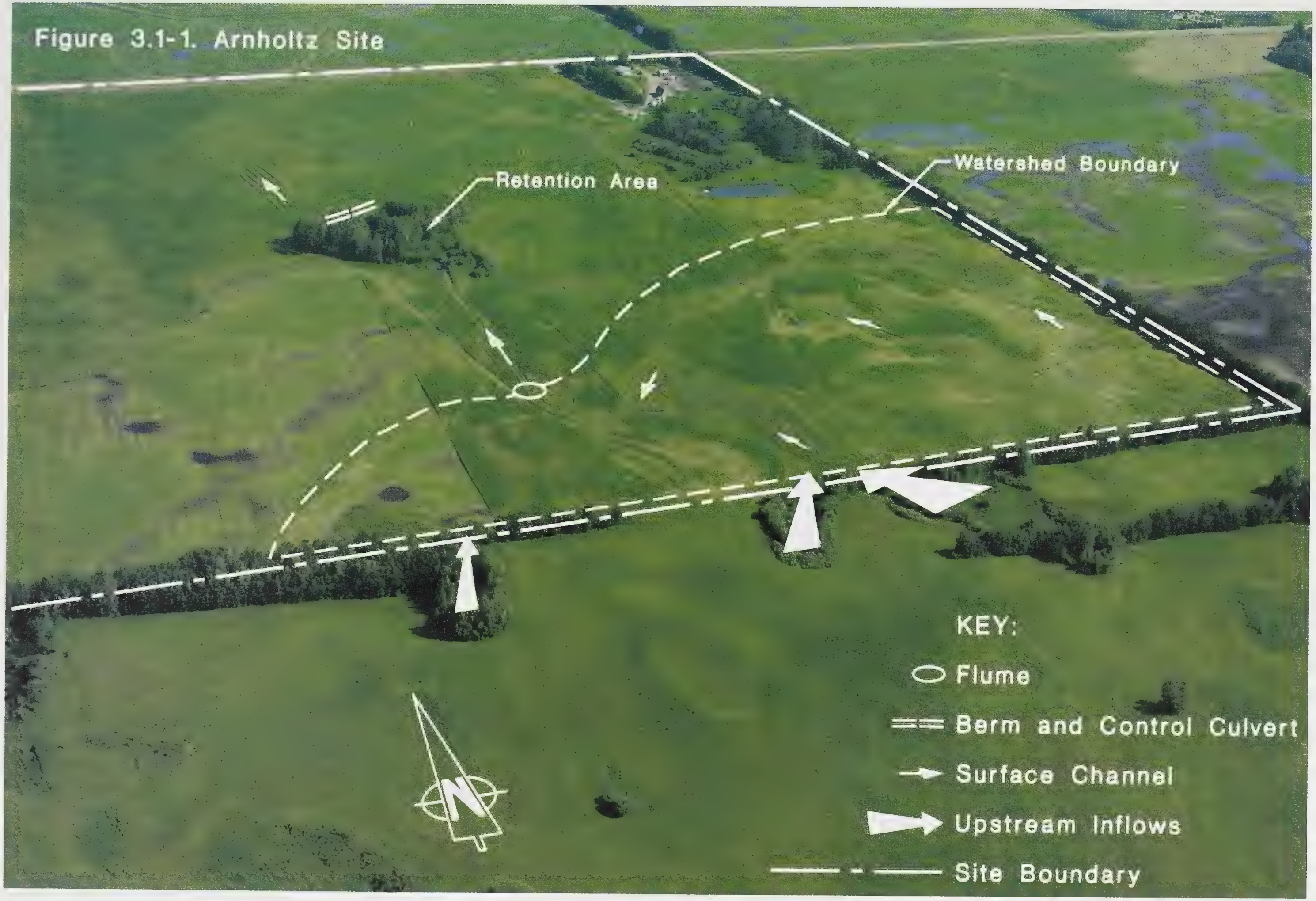


Figure 3.1-1. Arnholtz Site

the wet conditions. As a result, the ditches were too wet to be crossed by farm equipment most of the time, and only one depression was dry enough to be cultivated during the monitoring period.

An alternative design that would provide nearly complete drainage on the 16 ha watershed involves regrading of the ditches and removal of the flume. The deeper ditches of the alternative design, however, would likely further obstruct farm equipment operation and prevent improvements in farm efficiencies.

The capital cost of the as-built project including the retention area is $4,080; without the retention area, the estimated cost is about $3,000. The additional excavation and topsoil stripping needed to alter the as-built system to create the alternative design would add about $2,000 to this cost. If the alternative design had been constructed initially, the estimated capital cost without the retention area would have been about $3,400.

The principle factors affecting engineering designs for this watershed are the estimations of pre- and post-depressional storage volumes and snowmelt runoff volumes to size hydraulic controls to minimize off-farm impacts. Erosion control or determining a design flow are not important considerations because of the very flat slopes, and the size of ditches in comparison to the design flow.

3.1.3 Farm Practicality

Possible agronomic benefits from the uncontrolled drainage system on the 16 ha watershed include the following:

- additional acreage in annual crop production;
- improved field efficiency for field operations;
- improved timing of field operations and access to all parts of the field;
- increased production due to fewer weeds and improved moisture conditions in the transition zone*; and
- improved crop quality.

In 1989, all the drained depressions were seeded to perennial reed canary grass and, except for one depression, have not been harvested since due to the wet conditions. Thus, as of spring 1992, negligible additional acreage in crop production had been realized.

Field efficiency simulations calculated that if the depressional wetland areas on the site were eliminated, the potential reduction in fuel use and tillage time would probably be about 6.8%. However, with the as-built drainage system, there is no evidence to date that any of these efficiencies have been realized. The producer estimates about two days can be gained on spring seeding operations. However, it is unlikely that the timing of field operations has been substantially improved based on the small improvements in drainage achieved to date.

In the monitored drained transition zone, crop yields were far below those on adjacent uplands, and crop losses due to weed infestations continued to be a problem.

No significant difference in crop quality was observed between the three monitored locations. This indicates that possible crop quality improvements due to improved weed control, and fewer seeding and harvesting delays on the surrounding cropland have not been realized.

Based on this evaluation, no direct financial benefits can be attributed to this project and no financial analysis was conducted.

Project costs are $3,000, not including an estimated $1,500 for engineering design and supervision costs. Also, a tax appraisal indicates that possible property tax increases could amount to $85 per year, for a 9.7% increase.

Removal of the monitoring flume and regrading of the ditches might improve drainage sufficiently to allow cultivation of up to 2 ha out of the total 2.65 ha depressional wetland area. Field efficiency improvements are not anticipated, however, because of the obstructions created by deeper ditches in some locations.

It is important to note that the poor drainage achieved in this case study is the result of site-specific conditions and does not reflect the general effectiveness of uncontrolled drainage systems. In most cases, uncontrolled drainage rapidly removes water from depressional wetland areas.

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*Principal reasons cited by the landowner for this project.

3.1.4 Off-Farm Perspective

The surface hydrologic impact of the drainage system downstream of the Arnholtz quarter is expected to be negligible because the retention area appears to provide adequate storage to reduce any increase in peak flows created by the drainage system. Without the retention area, however, estimated peak flows for 10 to 25 year return period events would be 15% to 30% higher than pre-drainage conditions. Removing the flume and regrading to improve drainage could raise these peak flow increases to 30% to 50% higher than pre-drainage conditions.

An analysis was undertaken to determine the impact on off-farm costs if no retention area had been built on-farm. In general, an existing watercourse can accommodate some increased flow without significant damage or impact; however, if flows increase in the order of 30% to 50%, erosion control and channel improvements will be necessary. In the case of the Arnholtz project, a 7.2 km reach encompassing a drainage watershed of 10 km^2 was assessed as the impacted receiving stream. If the total 7.2 km reach had to be reconstructed to accommodate increased drainage of this watershed (based on the ratio of drained area to contributing watershed of the Arnholtz site), the total capital cost would be $232,000. This equates to $1,400 per drained hectare. If the drainage at the Arnholtz site was made more efficient and this increased efficiency was also applied to the rest of the 10 km^2 watershed, then the cost per drained hectare would increase to $1,435.

Groundwater conditions and wildlife densities and habitat were not monitored, but the project's relatively minor and imperfect drainage is not expected to have discernable consequences on these or other wetland functions.

Table 3.1-1 provides an evaluation summary of this project.

3.1.5 Project Conclusions

1. The as-built drainage system does not adequately drain the project watershed. As a result, the full potential agronomic benefits of the project cannot be achieved. Regrading and removal of the flume might improve drainage sufficiently to allow cultivation of about 2 ha out of the 2.65 ha depressional area.

2. With regrading and removal of the flume, uncontrolled drainage could provide nearly complete drainage at this site. The improved drainage design would be more expensive than the as-built design and the deeper ditch cuts would likely further obstruct farming operations. Even with the improved drainage design, the resulting net benefits are not expected to financially justify this project.

3. Rather than the commonly used approach of estimating peak runoff rates, the principle factors affecting engineering designs for the ditches, controls and retention requirements in this small, low slope watershed are determining pre- and post-depressional storage, required storage (for controlled drainage), and snowmelt runoff volumes, and estimating the contributing watershed area.

4. Without on-farm retention, peak flows resulting from this drainage project could be 15% to 30% greater than pre-drainage conditions. Regrading to improve drainage could increase peak flows to 30% to 50% more than pre-drainage conditions.

TABLE 3.1-1. Evaluation Summary, Arnholtz Project

Advantages	Disadvantages
1. Pre-Drainage Condition	
- Maintains 6 depressions, totalling 2.65 ha on average, for surface runoff control and other wetland functions - No added drainage costs either on-farm or off-farm.	- On average, 2.65 ha remain uncultivated. - Expected lower crop yields from 3.76 ha of transitional land around depressions and 9.59 ha of adjacent uplands. - Low field efficiency and timing of operations restricted by depressions.
2. As-built Surface Drainage with Downstream Retention Area	
- Possible 2 days gained on spring seeding operations (not confirmed). - Perceived aesthetic benefits.	- Capital cost of $4,080 plus engineering design support costs. - Possible property tax increases of about $85 per year. - Negligible increase in area cultivated. - No improvement in crop yields or quality to date. - No improvement in field efficiency to date. - Minor decrease in area and extent of ponding for wetland functions.
3. As-built Uncontrolled Surface Drainage without Downstream Retention Area	
- Same as for No. 2 above.	- Estimated capital cost of about $3,000. - Property tax increase as per No. 2 above. - Negligible increase in area cultivated. - No improvement in crop yields or quality to date. - No improvement in field efficiency to date. - Minor decrease in area and extent of ponding for wetland functions. - Off-farm increase in flood peaks of 15% to 30% for a 10 km^2 watershed, increase off-farm drainage costs to $1,400 per drained hectare, plus operations and maintenance costs of 2% per year.
4. Improved* Uncontrolled Surface Drainage Without Downstream Retention	
- Same as for No. 2 above. - Potential cultivation of up to an additional 2 ha. - Possible improvement in yields and crop quality (not confirmed).	- Estimated initial capital cost of about $3,400. - Property tax increases as per No. 2 above. - No improvement in field efficiency. - Off-farm increase in flood peaks of 30% to 50% for a 10 km^2 watershed, increased off-farm drainage costs to $1,435 per drained hectare plus operations and maintenance costs of 2% per year. - Decreased area and extent of ponding for wetland functions.

* Regraded ditch without the monitoring flume.

3.2 Glasier Project – Choked Controlled Drainage

3.2.1 Project Description

Site: The Glasier site is located 24 km west of Fairview, on the east half of 7-82-5-W6M. The general area has mildly undulating topography, with seasonal and temporary wetlands occupying depressions. Wheat and other grains are the main crops in the area.

The Glasier site includes two watersheds: a project watershed where the controlled drainage system was established; and a comparison watershed with a pre-existing, uncontrolled partially grassed waterway. The comparison watershed offered an opportunity to compare uncontrolled with controlled drainage.

The contributing drainage area of the project watershed varies, depending on snow and ice blockages and the size of the runoff event. Its usual contributing area is 78 ha, and its maximum contributing area is 173 ha. The 78 ha watershed has 13 depressions which were occupied by seasonal sloughs before drainage. The 254 ha comparison watershed is just south of the project watershed. The main ditches from the two watersheds join about 0.5 km east of the north-south road. The flow enters a coulee which drops 85 m to Hines Creek at a slope of over 7%.

Objectives: to assess, at the small watershed level, a controlled field ditch drainage system that retains runoff for two to four days, before crop damage occurs; and to evaluate the effects of the controlled drainage system on farm operations and on off-farm peak flows and erosion potential.

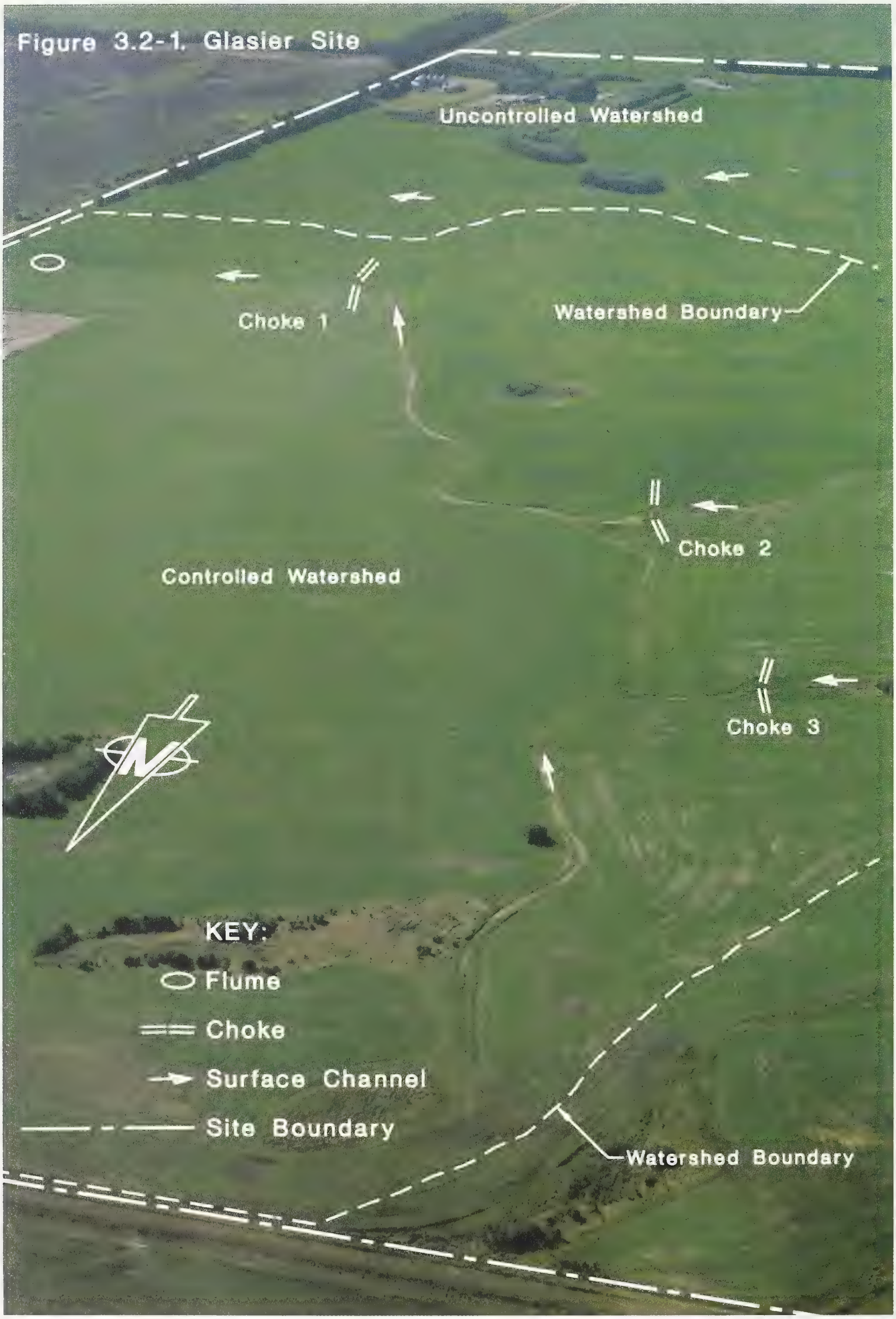
The flow of water in the ditches is controlled with choke structures. Chokes temporarily impound water when the runoff rates exceed the choke capacities. The resulting slow release of runoff minimizes downstream erosion and flooding. Also, the temporary runoff retention allows water to infiltrate the soil, thereby increasing the soil moisture available for later crop use and reducing the total volume of runoff released by the system. The system was designed to release a 1:10 year rainfall event over two days. This design criterion was established to ensure that runoff even from relatively large rainfall events would be removed before any crop damage occurred, and that snowmelt would be removed faster than under pre-drainage conditions. Although some crops will tolerate up to a four-day flood before crop damage occurs, some cereal crops will tolerate only a two-day flood. Therefore a two-day retention period was used for project design.

Water Management System: The project's water management system, shown on Figure 3.2-1, affects 32.6 ha within the Glasier half-section, including 5.68 ha of depressional land and 4.2 ha of transitional land. The system was designed to drain 13 depressions with swales or gently banked ditches. The ditches were designed to be crossed by farm equipment and cultivated. Three chokes were installed at the depression outlets to control the flow. The size and type of chokes appropriate for small watersheds were unknown at the start of the project and several designs were tested. A culvert through the north-south road at the downstream end of the property was replaced with a slightly larger culvert to provide somewhat better drainage on the Glasier site.

Costs: Total capital costs for the choked water management system are calculated to be $6,773, of which 21.6% was the producer's share. The capital costs include the costs of ditching and road culverts in 1988 ($4,718) and the 1990 choke installation costs, assuming the preferred gabion choke (see Section 3.2.2) is used at all three locations ($2,055). Additional research-related costs were: $1,057 for the initial chokes installed in 1988; $1,848 for ditch and choke rehabilitation in 1989; and $1,100 for the culvert on the north-south road.

Data Collection: Full data collection on the project watershed started in spring 1989 (after project construction in fall 1988) and continued to fall 1991. Agronomic data were collected at two locations in 1989 and 1990 (an upland control and a drained transition location); four other locations were added in 1991 (a drained depression, a drained transition, an upland control, and an undrained transition). The upland locations have Dark Gray Luvisols, and

Figure 3.2-1. Glasier Site



the transition and depression locations have Orthic Humic Gleysols. The site was seeded to wheat in 1989 and 1990, and to wheat and canola in 1991.

The comparison watershed was also monitored for outflow peaks and volumes.

3.2.2 Water Management System Evaluation

The choke designs used in this project were experimental. The original design was unsuccessful. It consisted of 150 mm diameter corrugated plastic pipes installed through berms at three locations. Estimated choke outflows were 20 L/s at low flow and 65 L/s at full flood. The plastic pipes were frozen solid the first spring following installation and the berms had to be breached to allow drainage. Therefore, chokes of this design are not suitable unless intensive maintenance is provided.

Because of the failure of the original choke design, the project watershed actually had uncontrolled drainage in 1989 and 1990.

In August 1990, three alternative chokes, were installed. The chokes, shown in Figures 3.2-2 to 3.2-4, were as follows:

Choke #1 (Cost $1,175): a treated plywood sheet with a 225 mm x 100 mm low level orifice and 600 mm wide overflow weir and mini-slab erosion protection downstream. Flow through the orifice is 50 L/s, and maximum weir and orifice flow is 190 L/s.

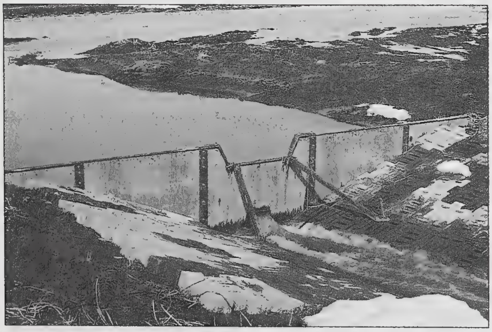


Figure 3.2-2 Weir and Low Level Orifice (Choke #1) at the Glasier Site

Choke #2 (Cost $615): a treated plywood sheet with a 150 mm wide vertical slot from the top of the plywood to the ditch bottom, and mini-slab erosion protection downstream. Maximum flow with a free outlet is 125 L/s, and with downstream water levels backflooding the slot, about 100 L/s.

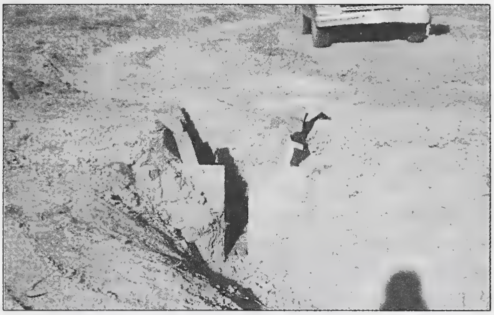


Figure 3.2-3 Vertical Slot Choke (Choke #2) at the Glasier Site

Choke #3 (Cost $685): a 4 m x 1 m x 1 m gabion (a rock-filled wire basket) with 75 to 100 mm sized rock fill and a 100 mm diameter perforated polyvinyl chloride pipe. Maximum flow is estimated at about 25 L/s.

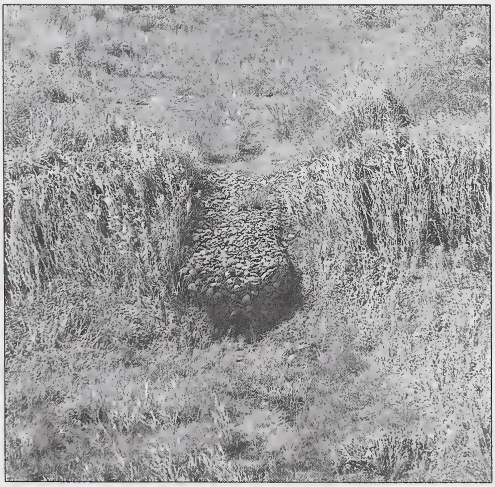


Figure 3.2-4 Gabion Choke (Choke #3) at the Glasier Site

Observations in 1991 suggest that all three chokes have merit. Each thawed on its own and provided a controlled release. The plywood slot, possibly because of the orientation and site-specific layout, took the longest to thaw and release the water held back. The slot should be narrower to decrease flow release rates when the choke does release the water.

The gabion choke appears to be the best alternative based on cost and its more gradual release rate. A gravel filter or filter cloth around the gabion is required to prevent erosion. Depending on the installation, the length of the gabion might be reduced to 2 or 3 m. Additional monitoring would be needed to fully assess the effectiveness of each choke design under differing spring melt conditions and the durability of the structures.

During the monitoring period, the ditches remained moist, primarily because of the flat slopes, and cultivation through the ditches was not possible. When the new chokes were installed in August 1990, the ditches upstream of the chokes were also regraded. As a result, the ditches and depressions will likely become drier through time. (Typically, after the disruption caused by construction, crop cover gradually becomes more uniform and rooting depths increase, resulting in greater soil moisture consumption in low lying areas.)

Hydrologic Impacts: Based on the 1991 data, choked drainage, as compared to uncontrolled drainage, can be very effective in reducing downstream peak flows and volumes by delaying runoff by 1 to 1.5 days and allowing greater infiltration.

Rainfall runoff was generally much less important than snowmelt runoff on this watershed. Rainfall events of at least one or two days' duration were generally necessary to saturate the soil and fill depressional storage in order to produce a runoff event. In 1991, no rainfall runoff events occurred.

During large snowmelt events, much of the project watershed is inundated. Under these conditions, the chokes back up the water in much the same way as pre-drainage conditions. Overland flow around the ditch system occurs so that the difference in peak flows between choked drainage and pre-drainage is very minor and limited to the flow capacity of the choke.

Estimates indicate that choking will result in peak discharges which are lower than peaks under uncontrolled drainage, but higher than peaks under pre-drainage conditions. Estimated runoff increases due to choked drainage and due to uncontrolled drainage, as compared to pre-drainage conditions, are shown in Table 3.2-1.

The data also suggest that the hydraulic capacities of the chokes could be reduced substantially, allowing water through at an even slower rate, and still be adequate to drain a 1:10 year event in less than four days, and thus minimize crop damage. Reducing choke capacities would have resulted in runoff peaks and volumes even closer to pre-drainage values than the ranges shown in Table 3.2-1. (Reduced choke capacities would have a negligible effect on costs.)

3.2.3 Farm Practicality

Agronomic Evaluation: Possible agronomic benefits of the controlled drainage works at this site include the following:

TABLE 3.2-1. Estimated Increases in Runoff Events (10 to 25 year Return Period) Compared to Pre-Drainage Conditions, Glasier Project

Runoff Events	Choked Drainage	Drainage Without Chokes (Uncontrolled Drainage)
Snowmelt Peaks	10 to 50%	100%+
Snowmelt Volumes	10 to 80%	200%+
Rainfall Peaks	15%+	40%+
Rainfall Volumes	30%+	200%+

- increased crop yields and additional acreage in crop production;
- improved field efficiency for operations;
- improved timing of field operations and access to all parts of the field*;
- reduced weed control problems*; and
- improved crop quality.

Because of start-up difficulties, cultivation of the drained areas was delayed. Part of the depressional wetland area was first cultivated in fall 1990 and seeded to wheat the following spring. Subtracting the remaining poorly drained depressions and ditch areas, an estimated 2.43 ha of depressional land has been brought under cultivation. In time and with additional effort by the producer, a marginal increase in this area might be achieved. The ditches will likely remain as uncultivated grassed waterways. Summer flooding of the 2.43 ha for four or more days (a crop killing flood) is not expected with the present choked drainage system, even for relatively severe storm events.

The crop yield data do not show any consistent year-to-year trends relating to the effects of drainage. The data also do not clearly indicate if the temporary water retention by the chokes significantly improves yields. Site yields were generally low: weighted average field-wide sample yields from the site were 60% of the regional values for canola and 94% of the regional values for wheat.

The crop quality data show no consistent trends from year to year, although quality may improve over time if more consistent moisture conditions are achieved. For the financial analysis below, a 1 grade improvement starting in 1991 was assumed.

No major change in field efficiencies has been experienced. Essentially, the original uncultivated and ill-defined diagonal channel across the quarter section has simply been converted into a well-defined diagonal ditch which still cannot be crossed by farm equipment on a regular basis.

The producer estimates up to five days for seeding and harvesting could be gained as a result of the drainage system. This is a significant amount of time to northern Alberta producers, but it is difficult to quantify this in relation to crop production because of the inconsistent crop yield and quality data.

Weeds appeared to be less of a problem at the drained transition locations in 1991 compared to 1990, which may be due to cropping part of the depressional wetland area. (The effects of any herbicide applications are unknown because data were not collected on this.)

Financial Evaluation: The above benefits are translated into farm financial estimates as summarized in Table 3.2-2. The benefits do not begin to accrue until 1991 because of the project's start-up difficulties. An appraisal indicates that property taxes could increase up to 14%, equivalent to about $40/year, on the controlled drainage quarter section.

The financial assessment uses the benefits and the costs listed in Table 3.2-2 and assumes that the producer paid 100% of the costs. The low Benefit/Cost (B/C) ratio and the large negative Internal Rate of Return (IRR) indicate that this project is not financially attractive.

Sensitivity tests were conducted to determine how responsive the B/C ratio and the IRR are to changes in the assumed benefits in crop production and to changes in cost-sharing (Table 3.2-3). The best B/C ratio in these sensitivity tests is only 0.51 (compared to the breakeven B/C ratio of 1.0).

The effects of using a 5% discount rate were also tested. The IRR is not affected because the IRR equals the discount rate where benefits equal costs. The B/C ratio is slightly but not significantly higher for the 5% rate.

If the findings from the project's choke experiments were applied to a similar project in the future, a more favourable rate of return would be expected. Assuming that such a project is completed in the initial year and the preferred gabion chokes with filters are used at all three locations, estimated capital costs would be about $5,674 plus the $1,100 for the road culvert downstream. Also, this road culvert could be considered as an off-farm expenditure and, therefore, excluded from the farm financial analysis. A reduction in the annual operating and maintenance expenses of up to

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*Principal reasons cited by the landowner for this project.

TABLE 3.2-2. Farm Costs, Benefits and Financial Assessment Summary, Glasier Project

Costs*		
1988 Capital Cost (ditching and east road culvert only)		$4,718
1990 Capital Cost (choke installation, assuming gabion chokes at all three locaitons)		$2,055
	TOTAL	$6,773
Operations and Maintenance (starting in 1989)		$175/year
Benefits (starting in 1991)		
Additional Crop Acreage (2.43 ha)		$176/year
Crop Quality Improvements (4.2 ha)		$79/year
Property Tax Increase		$(40)/year
	TOTAL	$215/year
Financial Assessment		
Assessment period (starting in 1988)		20 years
Commercial Interest Rate		10% per year
Full Costing Internal Rate of Return (IRR)		-17.6% per year
Benefit/Cost (B/C) Ratio		0.17

* Engineering design and supervision costs not included.

$100/year from $175/year might also be realized with the improved chokes after the first three years of operation (choke and ditch maintenance costs should decrease in time as the ditches stabilize). With these assumptions, the B/C ratio improves to 0.22 and the IRR becomes -8.9% per year. This suggests that even if the project had been fully operational from the beginning, it would not have had a good opportunity of realizing a favourable return for the producer unless initial capital costs are substantially reduced for him.

3.2.4 Off-Farm Perspective

Hydrologic Impacts: The choked water management system is expected to produce runoff peaks and volumes which are substantially lower than uncontrolled drainage values but somewhat higher than the pre-drainage values. As a result of the increase over pre-drainage conditions, flooding of the north-south road will be more frequent, the downstream landowner will need to improve his drainage system to accommodate this flow increase, and the steep coulee down to Hines Creek will experience more erosion, introducing more sediment to Hines Creek.

A retention structure at the start of the drop to Hines Creek would alleviate downstream erosion and flooding concerns. Estimated incremental costs applicable to the 32.6 ha in the project watershed on the Glasier property to alleviate these impacts, excluding neighbouring land costs, are $629 plus 2% per year for operations and maintenance. Without the chokes, this cost increases to $1,520 due to the increased flooding and erosion.

A cursory comparison of the costs of the three small chokes versus the costs of uncontrolled drainage on- site with one large control structure downstream of the site suggests the latter may be more cost-effective. To fully assess this option, the comparison would have to be extended over the entire watershed and include all costs (administrative, infrastructure, land, etc.). Furthermore, a downstream retention structure was considered when this project was developed but it was not acceptable to the downstream landowner because it would have flooded his land with no agronomic benefit to him. In such situations other incentives would be required to accommodate landowners' concerns about lost productivity for the benefit of upstream producers. In general, where landowners are located in similar areas of the Peace River region, that is,

TABLE 3.2-3. Sensitivity Tests and Confidence Intervals, Glasier Project

Variable	Simulated Change	Impact IRR (%)	 B/C
Base Case (100% paid by producer; actual production data)			
Discount Rate at 10%	--	-17.6	0.17
Discount Rate at 5%	--	-17.6	0.24
Optimistic Scenario			
1. Cropped Depression Area (4.86 ha)	2 x 2.43 ha		
2. Field Efficiencies	5%		
3. Crop Quality (4.2 ha)	2 grade improvement	0.4	0.51
Cost Sharing (base case benefits and costs)			
21.6% paid by producer (actual cost sharing)	21.6%	-8.1	0.47
50% paid by producer	50%	-13.6	0.29
75% paid by producer	75%	-16.0	0.21

adjacent to deeply incised channels without a network of naturally occurring wetlands along the channel, downstream retention structures will likely be difficult to site.

Other off-farm hydrologic impacts of the project include improved upstream drainage on the quarter section to the west. An estimated 7.5 ha of depressional land on this quarter is directly affected and the entire watershed upstream of the Glasier property (about 140 ha) is also affected to some extent by improved spring drainage. These impacts are considered minor and have not been quantified.

Other possible hydrological impacts, such as wildlife habitat losses, reductions in evaporation and reduced groundwater recharge which could reduce base flows in Hines Creek, were not evaluated in this study.

Economic Impacts: For the socio-economic assessment, the following changes and additions were made to the above farm financial analysis:

1. a longer time-frame (30 years) and a lower real discount rate (5% plus inflation);
2. world (free market) on-farm prices and costs, assumed as 90% of the financial net farm income;
3. off-farm resource quality and/or resource use changes;
4. wildlife-related impacts;
5. impacts on public infrastructure;
6. inclusion of overhead costs; and
7. other benefits and costs.

Off-farm resource impacts are a particular concern because of the need for improved drainage on the bordering property to the east and flow regulation or erosion control works on the coulee to Hines Creek.

Wildlife and recreation impacts were not evaluated at this site. A generalized average cost for wetland loss on the 2.43 ha area was assumed to be $254.91/year, based on a generalized average cost of $104.90 per ha per year, from Young and Thompson (1990). This speculative cost was assumed to start in 1991 because the depressional wetland area was not effectively drained until 1991.

Other potential cumulative environmental impacts of widespread drainage (including groundwater regimes, climatic impacts or other socio-economic and ecological functions) are not taken into account here but a cumulative net negative impact would be anticipated.

Capital costs of at least $1,500 for engineering/surveying and construction supervision, plus

TABLE 3.2-4. Socio-Economic Assessment Summary, Glasier Project

	Capital (Year Incurred)		Annual (Starting Year)	
Costs				
On-Farm	$6,773	(1988 & 1990)	$175	(1989)
Off-Farm	$629	(1988)	$13	(1989)
Wildlife	--		$255	(1991)
Other Overheads	$1,500	(1988)	--	
TOTAL	$8,902		$443	
Benefits				
On-Farm Socio-Economic	--		$193.50	(1991)
Socio-Economic Assessment				
Internal Rate of Return (IRR)		-∞		
Benefit/Cost (B/C) Ratio		0.12		

government administrative costs (permitting, monitoring, etc.) are not quantified in this analysis.

Results of the socio-economic analysis are summarized in Table 3.2-4.

The consistently negative net cash flow (IRR = -∞) and low B/C ratio 0.12 underline the previous finding that this is not a viable investment opportunity. Even complete removal of the speculative wildlife cost ($255/year) makes very little difference in the bottom line.

Table 3.2-5 provides an evaluation summary of this project.

3.2.5 Project Conclusions

1. In comparison to uncontrolled drainage, choked drainage can be very effective in reducing downstream peak flows and volumes by delaying runoff and allowing greater infiltration. This is especially evident on the smaller, more frequent flood events. Reducing the choke capacities will slightly reduce capital costs and reduce downstream flood impacts closer to pre-drainage values without sacrificing the agronomic benefits achieved.

2. The net benefits from this project, as constructed, are not expected to make this a viable project from a farm financial or socio-economic perspective. Although acreage has been added from about 40% of the drained depressions and timing of operations may have improved, these benefits are not adequate to financially justify the project. Even when very optimistic agronomic benefits are assumed, sensitivity analyses suggest that the financial viability of this project will not adequately improve.

3. The gabion choke with a surrounding filter is the preferred choke alternative for small watersheds, based on cost, ease of installation, controlled release rate and probable long-term stability. Long-term monitoring of the various choke designs would be needed to assess their function under varying spring melt conditions and with respect to long-term stability and erosion concerns.

4. Monitoring over a longer time-frame through a range of wet and dry growing seasons would be needed to adequately assess any effect of increased soil moisture on crop yields.

TABLE 3.2-5. Evaluation Summary, Glasier Project

Advantages	Disadvantages
1. Pre-Drainage Condition	
- Maintains 13 depressions totalling 5.68 ha in area for surface runoff control and other wetland functions. - No added drainage costs either on-farm or off-farm.	- Average area of 5.68 ha remains uncultivated. - Expected lower crop yields from 4.6 ha of transitional land around depressions but not substantiated by yield sampling. - Occasional spring flooding of roads. - Low field efficiency and restricted timing of operations due to depressions with related impacts on 22.72 ha of adjacent uplands.
2. As-built Controlled Surface Drainage	
- Estimated up to 5 seeding and harvesting days might be gained (not confirmed). - 2.43 ha of depressional land brought into production equivalent to upland yields with potential for a marginal increase in this area, value equivalent to about $176/year. - Reduced weed problems in drained transitions suggesting a 1 grade improvement in crop quality in this area (4.2 ha), equivalent to about $79/year. - Minor improvement in drainage of upstream watershed (140 ha) with 7.5 ha of depressional bordering land directly affected.	- Capital cost of $6,773 plus engineering design support costs estimated at $1,500 as a minimum. - Possible property tax increases estimated at $40/year. - No change in grain quality detected. - No improvement in field efficiency due to ditch obstructions. - Downstream increase in flood peaks of 10% to 50% costing at least $19.30/ha of watershed area affected, equivalent to $629 on the 32.6 ha drained on the Glasier project plus operation and maintenance costs of 2% per year ($13/year). - Operation and maintenance costs estimated at $175/year. - Loss of wetlands for wildlife and recreation assumed as $104.90/ha year, equivalent to $255/year plus other wetland function losses. - Administrative costs not quantified. - Farm financial B/C ratio is 0.17 and the IRR is -17.6% per year. - Socio-economic B/C ratio is 0.12 and the IRR is consistently negative (–∞).
3. Uncontrolled Surface Drainage	
- Same as for No. 2 above.	- Saves $2,055 in 1990 for choke construction compared to No. 2 above. - Downstream increase in flood peaks of over 100% compared to No. 1 above, costing $46.60/ha of watershed area affected, equivalent to $1,520 on the 32.6 ha drained on the Glasier project plus operation and maintenance costs of 2% per year ($30/year). - Increased flooding of north-south road. - Others as per No. 2 above (B/C ratio and IRR not computed).

3.3 Sipma Project – Slough Consolidation for Agriculture

3.3.1 Project Description

Site: The Sipma site is located between the Smoky and Peace Rivers on Section 20-81-23-W5M, about 28 km southwest of the town of Peace River. The general area consists of nearly level to undulating plains into which the Peace and Smoky Rivers are deeply incised. Cereals, oilseeds and forages are commonly grown on agricultural lands in the area. Much of the region is covered by boreal forest and muskeg.

The Sipma site, shown on Figure 3.3-1, is gently undulating with over 15 depressional wetland areas. It has 12.1 ha defined as depressional land and 20.4 ha defined as transitional land (including transitional areas along the project's ditches). The study watershed has a total area of 204.5 ha on the section. Flow leaves the section through a culvert on the section's east border and continues east across another section and then enters a coulee that drops about 215 m at a slope of over 10% to the Smoky River.

The western half of the Sipma section has rows of trees and underbrush (i.e., field shelterbelts) separating pastures. When the study began, the south central portion of the site was covered by dense bush which the producer has been gradually clearing.

Objectives: to investigate, at the small watershed level, the impact of surface drainage of spring runoff and storage of the drained water for livestock and supplemental irrigation, on farm operations and off-farm peak discharges.

Water Management System: The system was designed to drain the depressions by means of a main swale, running west to east across the section, and a branch joining the main swale near the centre of the section. The swales were to be passable by farm equipment in most places. The drained water was to be stored in two dugouts for stock watering. This type of water management system, in which water from several small water bodies is consolidated in one large water body, is called *slough consolidation* or *wetland consolidation*.

The two dugouts were excavated along the main swale, one near the west end of the watershed and the other near the centre. Excavated dugout storage capacity was designed to be nearly equivalent to pre-drainage depressional storage to maintain off-farm flood outflows to near pre-drainage conditions and to minimize downstream erosion especially in the coulee down to the Smoky River. Material from excavation of the central dugout was built into berms around the dugout so additional water could be pumped into it (Figure 3.3-2). To provide sufficient storage for the subsequent spring runoff, dugout water levels were to be lowered by using the water for supplemental irrigation.

When this project was designed, the Prairie Farm Rehabilitation Administration (PFRA) provided two-thirds cost-sharing for dugouts only if the dugouts met certain design specifications (e.g., a rectangular shape with relatively steep banks) and minimal to no cost-sharing for pumping stations. The project's dugouts were designed to maximize the amount of storage which would meet the criteria for PFRA cost-sharing.

Costs: Capital costs for this project totalled $27,560, of which 42.8% was paid by the producer. Also, an estimated $4,800 was paid by the producer in 1990-91 for pasture fencing. Operating and maintenance costs for dugout pumping, irrigation pumping and supplementary electric fencing are estimated to total $600/year.

Data Collection: Data collection at the Sipma site started in spring 1989 and continued to July 1991. Only 19.2 ha of the watershed was monitored for outflows (in an attempt to avoid the effects of the dugout storage). In 1989 and 1990, agronomic data were collected at three locations: an upland area (with Dark Gray Luvisolic soils); a drained depression (with Humic Luvic Gleysolic soils); and an undrained depression (with Orthic Gleysolic soils), which was a temporary wetland flooded only in the spring. In 1991, agronomic monitoring was restricted to crop yield and quality sampling but four locations were added: an undrained transition (with Orthic Humic and Orthic Luvic Gleysolic soils); an upland area not affected by the water management system (with Dark Gray

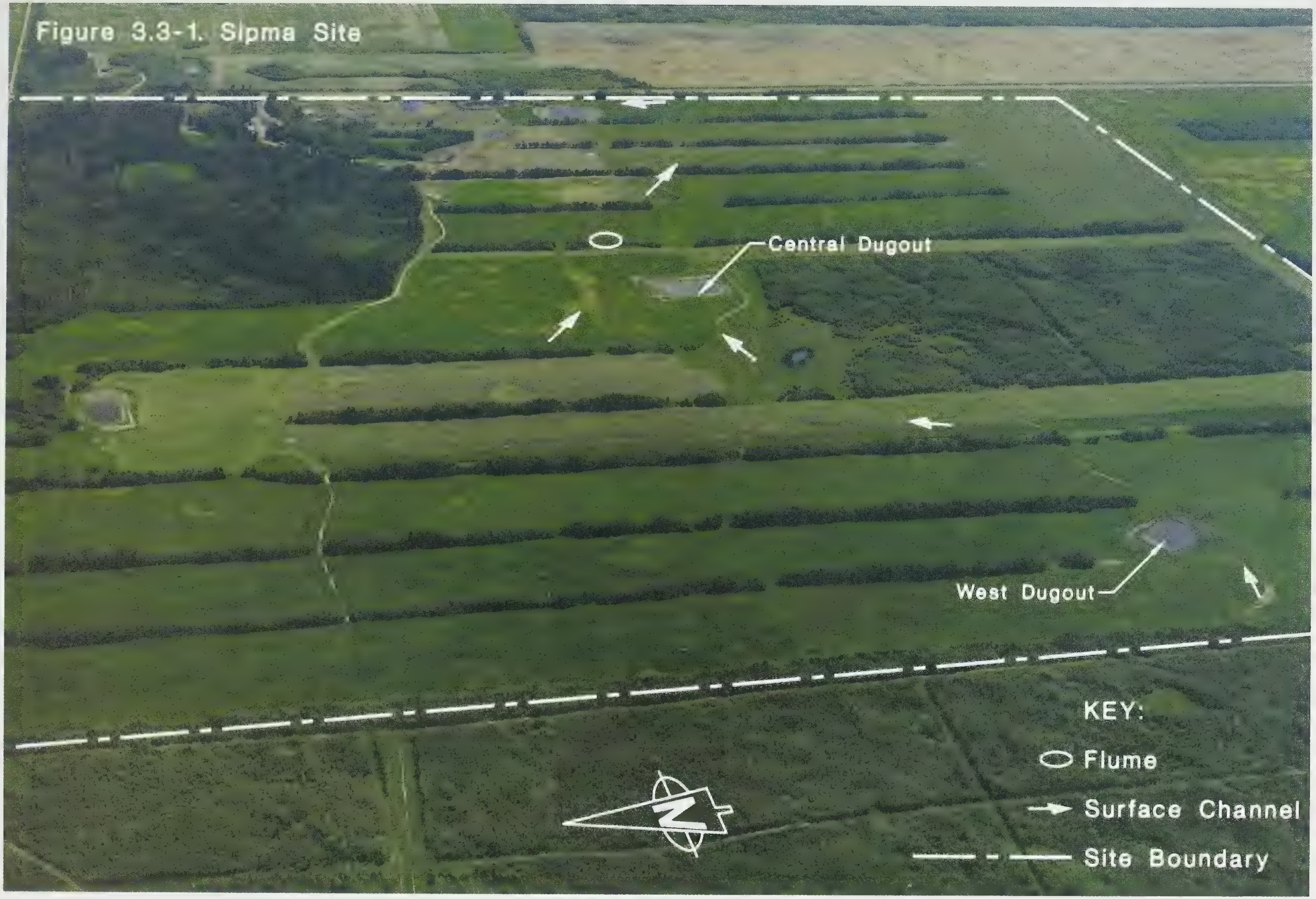
Figure 3.3-1. Sipma Site

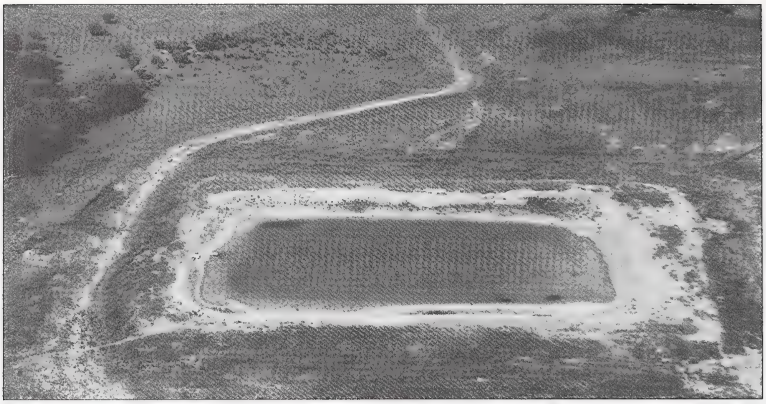

Figure 3.3-2 Central Dugout at the Sipma Site

Luvisolic soils); an irrigated upland (with Dark Gray Luvisolic soils); and a drained depression (with Orthic Humic and Orthic Luvic Gleysolic soils). The site was seeded to a grass-legume forage mixture during the monitoring period.

3.3.2 Water Management System Evaluation

The water management system has worked reasonably well at this site.

The swales were very effective overall. Spring drainage of the sloughs was achieved and the swales were generally passable by farm equipment. Steeper cuts in excess of 0.5 m in the central portion of the section were more difficult to cross. Ditch erosion was not a concern after some remedial measures were taken at the dugout inlets.

Even under relatively dry conditions, the water management system was able to store sufficient water to allow expansion of farm livestock operations. Runoff is directed into the two dugouts by opening culverts which connect the swales to the dugouts. The producer also uses a portable pump to surcharge the central dugout (i.e., to fill the dugout above the level possible by gravity storage). In addition to the two dugouts built for this project, the site has three dugouts which were in existence before the project started. These dugouts, located on the east side of the section, are used for stock watering and farmstead purposes. Pre-construction depressional storage was about 16,500 m^3. After construction, the depressions still retained about 1,700 m^3. Total available dugout and depressional storage (excluding the central dugout's bermed storage) after construction is 19,500 m^3.

The major operational limitation of the project is the filling and surcharging the dugouts in the spring. Both regionally and at the site, runoff typically occurs only in the spring. Thus it is very important to store available spring runoff for use later in the year, particularly for livestock operations. Several difficulties were encountered with the as-constructed system: the relatively short time available to collect spring runoff (typically one week with two to three prime days in this week); the lack of good ditch blocks to divert water into the dugouts; and overnight freeze-up of the pump. The berm storage for the central dugout was not fully used because an effective pumping system was not installed there.

Possible design concept modifications are as follows:

1. *Design larger dugouts* that do not rely on surcharging. This would relieve operational concerns and provide additional storage, but would take up more land and would not use the storage created by dugout berms. Also, it could be more expensive because the deeper a dugout is excavated, the higher the excavation costs.

2. *Construct backwater control structures* (berms preferably with gates or stoplogs, or simply hay bales) to redirect more water

into the dugouts. The ability to do this at low cost depends on site-specific landscape features. At the Sipma site, backup of about 0.3 m could have been achieved without extensive berming. With a backup structure, more water would flow by gravity into the dugouts and also be retained for eventual pumping into the dugout.

3. *Locate the dugouts on-line* with the ditches to allow the water to flow into the dugouts without pumping. Neither Alberta Agriculture and Rural Development nor PFRA recommend locating dugouts on-line because of concerns with reduced dugout water quality and impacts during a major flood or back-to-back floods in the event of breaching the elevated berms. More stringent site-specific design guidelines would be needed if the dugouts were located on-line. A low-cost bypass spillway around each dugout, however, could eliminate potential flood impacts and automatically set the maximum level of the dugout.

4. *Modify the dugout design* to take better advantage of the natural site contours or enhance waterfowl habitat. Such modifications would not have met PFRA's cost-sharing criteria but might have been more economical or functional for this system.

Hydrologic Impacts: Adequate spring drainage of about 12.1 ha of depressional land is achieved with the ditches. Spring runoff estimates suggest that the water supply may become a limiting factor to operations in one year out of four. However, 3,000 to 4,000 m^3 carryover storage from one year to the next should eliminate this concern. Without the drainage and water storage system, expansion of farm operations would have been less viable at this site because of water supply concerns.

The producer uses an irrigation gun to apply dugout water to adjacent forage land. In at least six out of 10 years, more than adequate storage can be provided to allow irrigation during key growth periods.

3.3.3 Farm Practicality

Agronomic Evaluation: The main agronomic benefit of the water management system at this site is the establishment of rotational grazing and a net increase in the overall livestock carrying capacity of the farm. Other related potential agronomic benefits include:

- increased area of forage production;*
- improved crop quality;
- improved field efficiency and timing for field operations;*
- reduced weed control problems and increased production due to fewer weeds in transition zones with increased yields from supplemental irrigation in other areas;* and,
- improved water supply for livestock.*

Before this project was implemented, the producer constantly faced the risk of water shortages. In some years he had to truck in water for his livestock operation. The dugout storage system supplies sufficient water to operate a rotational grazing program over the site's entire pasture. Water supply is no longer a limiting concern. Since construction, herd size has increased from 100 to 150 head of cattle. The producer estimates an overall 35% increase in livestock productivity.

An estimated 9.1 ha of the 12.1 ha of depressional land has been drained. In dry years, some drained depressions may have poorer yields, due to lower soil moisture, than the undrained depressions, but drainage has increased the total area under forage production so there is likely a net increase in total crop yield.

The limited yield data from the transition areas was insufficient to indicate any difference in yield as a result of drainage.

Although a yield increase might be expected from supplemental irrigation, yields for the irrigated upland areas during the monitoring period were lower than the non-irrigated upland yields. The reasons for this could be related to factors specific to the monitoring location. At least at this site, irrigation may be more important for lowering dugout water levels, without releasing water downstream, in

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*Principal reasons cited by the landowner for this project.

TABLE 3.3-1. Farm Costs, Benefits and Financial Assessment Summary, Sipma Project

Costs*	
1988 Capital Cost (dugouts, berm, main ditch, culverts)	$22,514
1989 Capital Cost (berm topsoil, erosion protection, culvert installation)	5,046
1991 Capital Cost (pasture fencing)	4,800
TOTAL	$32,360
Operating and Maintenance (pumping and electric fencing, starting in 1990)	$600/Year
Benefits	
Livestock Productivity Increase (starting with half annual benefits in 1990)	$2,335/Year
Financial Assessment	
Commercial Interest Rate	10%/Year
Assessment Period	20 Years
Full Costing Internal Rate of Return (IRR)	-0.68%/Year
Benefit/Cost (B/C) Ratio	0.47

* Engineering design and supervision costs excluded.

order to create sufficient storage for the following spring runoff.

The data suggest that forage quality has not been affected by the drainage system.

Some improvements to the timing and efficiency of field operations (fertilization, haying) may have taken place, but these are difficult to estimate. In some areas, the drainage ditches have created new barriers to operations.

Financial Evaluation: The end result of the above benefits is an increase in livestock carrying capacity estimated to be 280 animal unit months**, amounting to $2,335/year. Despite this, a registered appraiser suggests no property tax changes are anticipated due to this project. The financial assessment is based on the above benefits and the costs listed in Table 3.3-1 and assumes the producer paid 100% of the costs. The assessment suggests the rate of return would be below breakeven.

Sensitivity analyses, summarized in Table 3.3-2, were conducted using the following alternative scenarios:

1. ±20% change in the total annual revenue projections; and,
2. The ramifications of various cost-sharing arrangements or, alternatively, reductions in capital costs.

Applying the actual producer cost (i.e., 42.8% paid by the producer) with the projected Base Case net revenue stream, an IRR of nearly 7% per annum is anticipated. Combining the actual producer cost with the more optimistic scenario, the IRR would increase to 10.1% per annum (where the B/C ratio is 1.01). A less expensive water management system, such as using bales rather than culverts to redirect runoff to the dugouts, would have further improved the IRR and B/C ratio.

3.3.4 Off-Farm Perspective

Environmental Impacts: The volume of dugout storage created by the project is greater than the drained depressional storage. Under the present conditions the producer drains the dugouts (by using the water for irrigation) to about one-third capacity in the fall in order to capture the next spring's runoff. Assuming a modest amount of surcharging of the dugouts in the spring, this will more than compensate for the increased runoff as a result of the drainage works. Downstream off-farm impacts

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**An animal unit month is a measure of the forage or feed required to maintain one animal unit, i.e., a mature cow of 455 kg (1,000 lbs) or equivalent, for 30 days.

TABLE 3.3-2. Sensitivity Tests and Confidence Intervals, Sipma Project

Variable	Simulated Change	Impact IRR (%)	Impact B/C
Base Case (100% paid by producer, actual production data)	--	-0.68	0.47
Upper Limit			
Projected Monetary Benefits Increase 20%	+20%	1.71	0.56
Lower Limit			
Projected Monetary Benefits Decrease 20%	-20%	-3.56	0.37
Cost Sharing (with base case benefits)			
42.8% paid by producer (actual cost sharing)	42.8%	6.84	0.84
50% paid by producer	50%	5.36	0.76
75% paid by producer	75%	1.73	0.58

as a result of this project are therefore expected to be negligible, providing the system is able to capture runoff.

Without dugout storage at this site, the downstream impacts of the drainage would be significant. The culvert at the road crossing would be undersized, the downstream drainage channel would be inadequate and extensive erosion of the coulee down to the Smoky River could occur. The estimated increase in the design peak flows from pre-drainage to uncontrolled drainage is 10% to 20%.

Other environmental factors potentially affected by drainage (e.g., groundwater conditions and wildlife habitat) were not monitored.

Economic Impacts: A socio-economic assessment was conducted with the following changes and additions to the financial analysis:

1. a 30-year time-frame and a real 5% discount rate, plus inflation;
2. world (free market) on-farm prices and costs (since beef operations are already in an essentially free market situation, no financial price adjustments are required for this analysis);
3. off-farm resource quality and/or resource use changes (expected to be negligible in this case);
4. wildlife-related impacts (not included because they could not be quantified);
5. impacts on physical (public) infrastructure (none identified);
6. inclusion of overhead costs (assumed as $1,500, as a minimum, for engineering/surveying and construction supervision with administrative costs not identified); and
7. other benefits and costs (i.e., other environmental implications, not quantified but expected to be a net negative impact).

The results of this assessment are summarized in Table 3.3-3.

These estimates show a positive IRR and a B/C ratio approaching unity which, though still below breakeven, are relatively high compared to the values obtained for the four study sites with annual crops.

Table 3.3-4 provides an overall evaluation summary of this project.

TABLE 3.3-3. Socio-Economic Costs, Benefits and Assessment Summary, Sipma Project

	Capital	Annual
Costs		
Capital Costs (as per Table 3.3-1)	$32,360	--
Operating and Maintenance	--	$600/Year
Overheads	$1,500	--
Benefits		
Livestock Productivity Increase	--	$2,335/Year
Socio-Economic Assessment		
Discount Rate	5%	
Assessment Period	30 Years	
Internal Rate of Return (IRR)	2.4%/Year	
Benefit/Cost Ratio	0.78	

3.3.5 Project Conclusions

1. The drainage and dugout storage system resulted in a significant positive change in the farm operations, including a 35% increase in livestock productivity, a decreased risk of water shortage, increased acreage in forage production, and improvements in timing and efficiency of operations. However, the farm financial B/C ratio was less than breakeven due to the high capital costs and the ongoing water management costs.

2. The on-farm storage, in addition to providing a needed water supply, adequately reduces runoff rates so that downstream off-farm hydrologic impacts are negligible.

3. At the site, runoff typically occurs only in the spring which suggests that water management systems in this area should be designed for snowmelt rather than rainfall conditions.

4. Pumping to bermed dugouts would maximize the storage available at this site. Such a system would have higher costs for the purchase and operation of the pumping system but could have lower dugout excavation costs. Further study would be needed to fully evaluate the costs and benefits of bermed dugout storage.

TABLE 3.3-4. Evaluation Summary, Sipma Project

Advantages	Disadvantages
1. Pre-Drainage Condition	
- Maintains about 15 depressions totalling 12.1 ha in area, maintaining natural runoff control and other wetland functions. - No added drainage costs either on-farm or off-farm.	- Average depressional wetland area of 12.1 ha uncultivated. - Expected lower crop yields from 20.4 ha of transitional land (no data collection to substantiate this) - Lower field efficiency and timing of operations somewhat restricted with related impacts on 134.5 ha of upland pasture. - Livestock carrying capacity limited by water supply (pre-project level of 100 cows); trucking of water required in dry years.
2. As-Built Surface Drainage with Slough Consolidation to Dugouts	
- A more dependable water supply permitting establishment of a rotational grazing program. - Improved drainage on 9.1 ha of depressional land and 15.4 ha of transitional land resulting in a net gain in forage production from these areas. - Increased livestock carrying capacity, equivalent to about a 35% productivity increase with 150 cows in 1991. - Improvements in timing and efficiency of operations in some areas. - No change in off-farm hydrologic impacts. - No property tax change expected.	- Capital cost of $32,360 plus operating and maintenance costs of $600 per year plus engineering design and support costs. - Need to manage water, capture runoff and surcharge dugouts during spring runoff and lower dugouts in later summer; no detected increase in yields on irrigated area. - Loss of 9.1 ha of depressional land for various wetland functions with some offsetting effects of dugouts. - No measured improvement in forage quality. - Farm financial B/C ratio is 0.47 and IRR is -0.68%/year. - Socio-economic B/C ratio is 0.78 and IRR is 2.4%/year. - Ditch restrictions to field operations in some areas.
3. Uncontrolled Drainage	
- Improved drainage on 9.1 ha of depressional land and 15.4 ha of transitional land resulting in a net gain in forage production from these areas. - Improvements in timing and efficiency of operations in some areas.	- No improvement in water supply and as a result no improvement in livestock carrying capacity. - Increased need to truck water in dry years. - Capital cost of about $3,000 for ditching only, plus minor operating and maintenance costs. - Loss of depressions for various wetland functions. - 10 to 20% increase in flood peaks downstream costing $1,470 ($8.50/ha) for the 204.5 ha drained plus operating and maintenance costs of 2% per year. - Ditch restrictions to field operations in some areas.

3.4 Olson Project – Slough Consolidation for Agriculture/Waterfowl

3.4.1 Project Description

Site: This site is located about 7 km south of the Peace River and 12 km north of Rycroft, on the northeast quarter of 24-79-5-W6M. The quarter is part of a 210 ha watershed. The watershed drains north through a poorly defined channel for 700 m where the flow enters a natural ravine which drops 180 m at a slope of about 10% to Dunvegan Creek.

The site is in an area of gently rolling knolls separated by broad, relatively level depressional wetland areas. Prior to drainage, the site had about 25 wetlands (including two dugouts), with an area of 14.2 ha. The depressions were not cultivated and contained permanent and seasonal wetlands. The depressions were surrounded by transitional land totalling 9.0 ha. As well, 38.5 ha of uplands were affected by low field efficiency and restricted timing of operations due to the depressions.

Large numbers of migrating waterfowl use the Peace River region for breeding and for migration to and from more northern breeding sites (Bellrose, 1976). The Olson site under natural conditions had moderate limitations to waterfowl production (Weaver, 1971). Annual cropping practices in the surrounding area have removed much of the natural permanent waterfowl nesting cover, with the exception of wetland fringes on several large seasonal and permanent wetlands, and blocks of tree-shrub communities. The Olson site has bush bordering its south side and a 15.2 ha block of aspen forest along the west edge of the project's consolidation pond.

Objectives: to demonstrate and evaluate, at the small watershed level, the effects of slough consolidation on farm operations and off-farm peak runoff rates; to evaluate the effects of slough consolidation on waterfowl; to assess the compatibility of waterfowl and agricultural land uses; and to evaluate the effectiveness of the habitat enhancement measures.

Water Management System: The water management system, shown on Figure 3.4-1, was designed to drain approximately 23 temporary, seasonal and permanent wetlands. The system provided temporary and permanent on-farm storage for the drained water to minimize potential downstream erosion and flooding, increase soil moisture content, and provide wetland habitat for waterfowl and other wildlife.

Two drainage systems were constructed: surface ditches with a backflood control weir (Figure 3.4-2); and perforated subsurface tubing with Jensen inlets (Figure 3.4-3). *Backflooding* is a method for temporarily retaining water and then gradually releasing it by means of an operator-controlled device. Temporary storage allows runoff time to infiltrate the soil or evaporate, thereby reducing runoff peaks and volumes, and increasing soil moisture. The weir backfloods a portion the ditches and the Jensen inlets can be closed to backflood the depressions.

The surface and subsurface systems combined have a total watershed of 61.9 ha within the quarter section. Water from these two systems is pumped into a consolidation pond in the northwest corner of the quarter section. The pond has a buried slow release line for delayed and controlled release of pond water to minimize downstream erosion and flooding.

Waterfowl Habitat Enhancement: Waterfowl need a variety of wetland types in combination with upland cover to meet their needs for pair distribution, reproduction, feeding and rearing of young, and migratory staging. For example, many species need shallow wetland areas in the spring for food supplies and mating, grass and shrub meadows in the late spring for nesting, seasonal and permanent marshes for brood rearing in early summer and open water areas for moulting and staging. Temporary, seasonal and permanent wetlands and upland cover also provide a variety of food sources throughout the open water season.

The Olson consolidation pond, shown in Figure 3.4-4, was designed to provide a mix of wetland types in an attempt to replace some of the waterfowl habitat lost due to drainage. Pond enhancement measures included:

- creation of two permanent water areas connected by a ditch;
- minor recontouring to create permanent, temporary, seasonal and semi-permanent

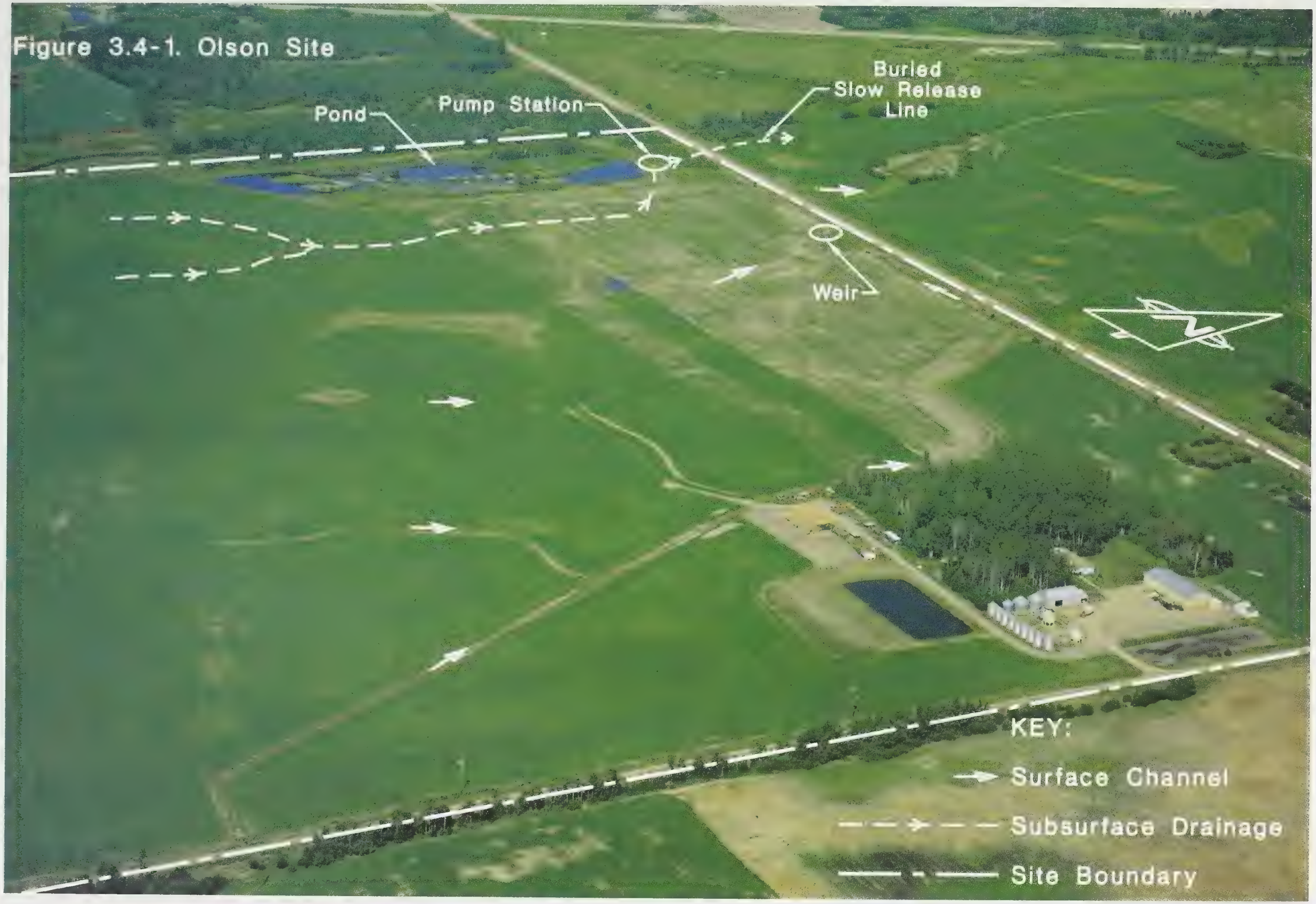

Figure 3.4-1. Olson Site

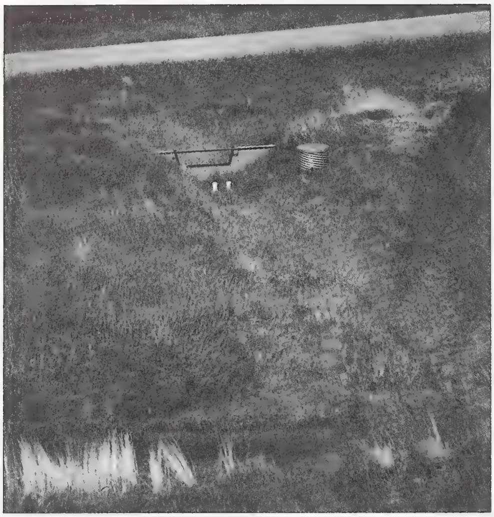

Figure 3.4-2 Weir and Drain Inlets at the Downstream End of the Main Channel at the Olson Site

areas in the pond;
- creation of nesting and resting islands; and
- establishment of shrub and tree cover in some upland areas around the pond.

The pre-existing wooded area adjacent to the consolidation pond provided additional wildlife habitat. Also, the pond's slow release line allowed regulation of pond water levels for waterfowl habitat purposes.

Costs: The initial capital cost of this project was $33,614 with about 40% paid by the producer. In addition, about $7,383 was expended for waterfowl habitat enhancement. Annual operating and maintenance costs were estimated at $700/year.

Data Collection: Hydrologic data were collected over four seasons from spring 1988 to fall 1991. Snowmelt runoff results were also reported for spring 1986. Agronomic sampling was conducted over three years. In 1989 and 1990, agronomic monitoring locations consisted of an upland location with Dark Gray Luvisols and a subsurface drained location with Orthic Humic Gleysols. The crop was harvested before sampling took place in 1989 and therefore a full square metre sample could not be obtained. In 1991 three agronomic monitoring locations were added: a subsurface drained transition location with Orthic Humic Gleysols, a surface drained transition location with Orthic Humic Gleysols, and an upland location with Dark Gray Luvisols. Waterfowl monitoring was conducted in 1988, 1989 and 1990 although the monitoring program varied substantially from year to year.

3.4.2 Water Management System Evaluation

Overall, the water management system worked well according to the design. Peak outflows from the pond and slow release line were estimated to be only 2% to 4% higher than under pre-drainage conditions.

The consolidation pond with the buried slow release line provided adequate storage under most runoff conditions; only in June 1990 during an extremely large rainfall event, with a 1:45 year return period, was pond capacity exceeded. The automatically controlled pond drawdown rates observed during the study indicate the slow release line operates at very close to its design capacity and provides a very effective delayed and controlled release to minimize downstream erosion potential.

Ditch erosion did not appear to be a problem, particularly because of the backflood system

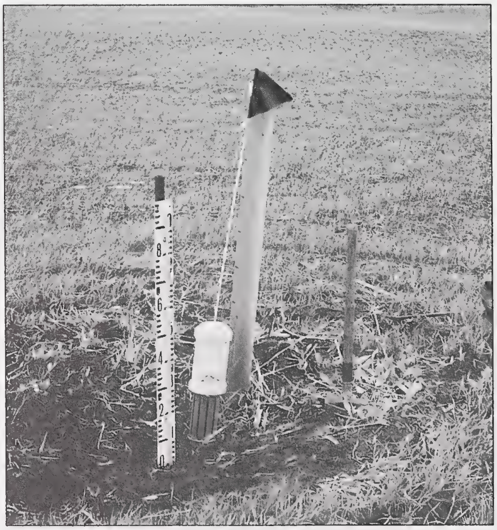

Figure 3.4-3 Jensen Inlet to Subsurface Drainage System

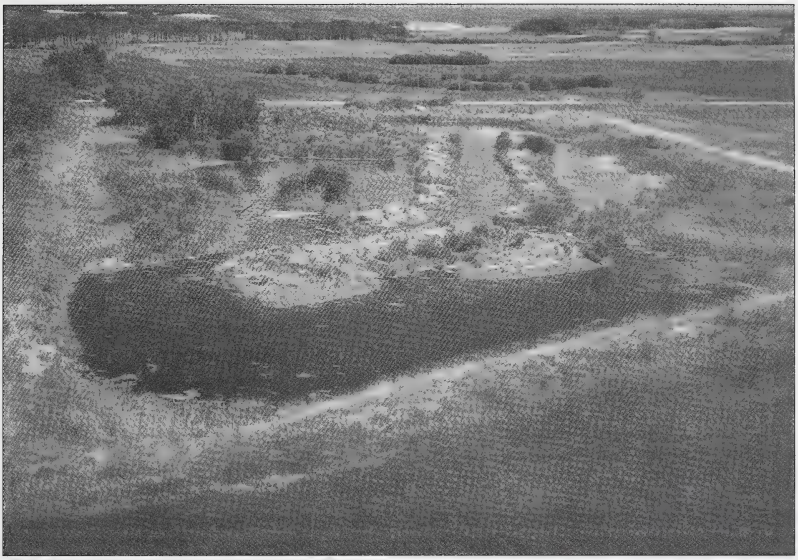

Figure 3.4-4 Olson Consolidation Pond and Islands

for the ditches. The main ditch obstructs farm operations but provides effective drainage at a very low slope.

For this site, the subsurface system was more advantageous than the surface ditches. It provided slightly better drainage for crop production than the surface system and did not obstruct farm equipment operation. The Jensen inlets are easily damaged and require ongoing maintenance but the surface ditches also require maintenance. In general, however, the choice between a surface and a subsurface system will be dictated by the topography, the influence of upstream inflows, other site-specific considerations and capital cost.

The combined capacity of the surface and subsurface system pumps used at this site was very close to the estimated required rate to drain the area during the 1:10 year design rainfall event. A slightly larger pump on the surface system and a smaller pump on the subsurface system would have been more appropriate.

Waterfowl Habitat Enhancement Measures: The vegetation in and around the consolidation pond did not become well established until 1991 because of very dry conditions. Measures which could have improved waterfowl habitat immediately after the pond was created include:

- reseeding of the nesting and resting islands with an appropriate mix of grasses and forbs;
- establishing and maintaining dense, permanent nesting cover in areas adjacent to the pond; and
- establishing emergent aquatic vegetation (such as cattails and bulrushes) in the shallow areas.

Good opportunities for upland habitat enhancement are also available in the tree and shrub area to the west of the consolidation pond.

Hydrologic Impacts: Increases in downstream flood flows are expected to be very minor because of the controls built into the water management system. The weir control structure adequately backfloods the surface drainage system during major runoff events such that runoff peaks and volumes from the Olson site are expected to be very similar to pre-drainage conditions.

Hypothetical computations for uncontrolled drainage conditions (including some short-term storage due to imperfect drainage) suggest peak outflows would be 40% to 50% greater than pre-drainage conditions during the major events observed at this site. Similarly, runoff volumes would be 30% to 60% more for these events. These volumes might be further increased by an additional 5% to 10% because uncontrolled drainage allows very little infiltration.

Uncontrolled surface drainage on the entire Olson quarter could have been achieved, but extensive cuts up to 1.5 m deep in areas now drained by the subsurface system would have been required. Even excluding the off-farm hydrologic impacts, the severe restrictions to farm operations created by such ditches, the excavation expenses and potential on-farm erosion concerns make this an unrealistic option for this site.

3.4.3 Farm Practicality

Agronomic Evaluation: Possible agronomic benefits of the drainage works constructed at this site include the following:

- additional acreage in crop production;
- improved field efficiency for operations;
- improved timing of field operations and earlier access to all parts of the field*;
- reduced weed control problems; and
- improved crop quality.

The drainage works have increased the total average annual area of production by about 20% (9.5 ha). Minor crop losses due to summer flooding and inadequate drainage of the main ditch and two remaining depressional wetland areas are expected to affect, on average, about 2.1 ha.

The subsurface drained depressions produced 16% to 35% higher yields than the upland areas except in years with extremely heavy rainfall events. These depressions remained moister than the uplands so when little precipitation occurred the depressions still had moisture available for crop growth. The drier the season, the greater the difference between yields from the depressions and the uplands.

Although pre-drainage transition area yields were likely depressed because of poorer soil conditions (frequent excess moisture resulting in ruts, a poorer seed bed, etc.) and weed infestations, this cannot be confirmed because no undrained transitions were monitored and weed treatments were not recorded. Yield samples in the drained transitions were inconsistent (i.e., both higher and lower than upland yields).

The drainage system is expected to allow field operations to begin earlier in the year and to allow access to isolated knolls even in wet years. The main quantifiable benefits of this are expected to show up in field efficiencies and crop quality. Field efficiency simulations estimated a gain of 3.3% due to fewer obstacles.

The improved timing of field operations, reduced weed control problems and more homogeneous moisture conditions throughout the field can result in improved crop quality. Although not substantiated by the limited sampling program, an average 1 grade improvement in crop quality on the 9 ha of transitional land is expected to occur from the above benefits.

Financial Evaluation: The above agronomic benefits are translated into farm financial estimates as summarized in Table 3.4-1. The financial assessment uses the benefits and costs listed in the table and assumes the producer paid 100% of the costs. An appraiser estimated that the increase in agricultural productivity would increase the property tax by about 11% or $24 per year. For this analysis, the operating and maintenance costs are assumed to be $200/year for the first 10 years of operation and $700 thereafter, because Jensen Engineering Ltd. is paying power costs, estimated at $500 per year, for the first 10 years. Actual power costs ranged from $168 to $280 per year, plus operation and maintenance costs of $420 per year for a separate transformer at the pond. Assuming the producer had extended his service from the farmstead and paid all actual costs, the bottom line would still be similar to that shown in Table 3.4-1.

Based on this assessment, this water management project is unlikely to generate an adequate rate of return to the producer without cost-sharing. Investment and operating and maintenance costs are relatively high compared to ongoing annual monetary benefits.

Sensitivity tests conducted to illustrate potential variations in the B/C ratio and the IRR were based on two considerations:

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* Principal reasons cited by the producer for this project, in addition to protecting wildlife habitat on the property.

TABLE 3.4-1. Farm Costs, Benefits and Financial Assessment Summary, Olson Project

Costs		
1985 Capital Cost (earthwork, power, pumps, sumps, pipes, etc.)		$33,614
Operating and Maintenance (power $500/year, ditch clearing, inlet repairs, fencing around the pond, etc. $200/year)		$700/Year
Benefits		
Additional Cropped Acreage		$1,006/Year
Transition Area Yields		$116/Year
Field Efficiencies		$111/Year
Crop Quality		$186/Year
Property Tax Increases		($24)/Year
	TOTAL	$1,395/Year
Financial Assessment		
Assessment Period (Starting in 1985)		20 Year
Commercial Interest Rate		10% per Year
Full Costing Internal Rate of Return (IRR)		-6.1% per Year
Benefit/Cost (B/C) Ratio		0.32

1. A 20% change in the total annual revenue projections; and
2. The ramifications of various cost-sharing arrangements or, alternatively, reductions in the total capital cost from the producer's perspective.

These tests, summarized in Table 3.4-2, strengthen the conclusion that this project would not likely generate an adequate net rate of return to the producer.

3.4.4 Off-Farm Perspective

Hydrologic Impacts: Prior to drainage, upstream runoff entered this quarter with excess runoff draining north to the ravine. The same situation occurs with the as-built system and, based on the monitoring observations, the system does not create any downstream impacts other than those which would have occurred under pre-drainage conditions.

TABLE 3.4-2. Sensitivity Tests and Confidence Intervals, Olson Project

		Impact	
Variable	Simulated Change	IRR (%)	B/C
Base Case (100% paid by producer; actual crop production data)		-6.1	0.32
Upper Limit			
Projected Monetary Benefits Increase 20%	+20%	-3.7	0.38
Lower Limit			
Projected Monetary Benefits Decrease 20%	-20%	-9.5	0.25
Cost Sharing (with base case benefits)			
40% paid by producer (actual cost sharing)	40%	3.7	0.72
50% paid for by producer	50%	0.9	0.60
75% paid by producer	75%	-3.5	0.42

The buried slow release line to the channel downstream of the site eliminates any concerns with a long duration trickling of drainage water across the neighbour's farm and downstream erosion. Without a slow release line, the consolidation pond storage capacity of 21,400 m^3 would have to have been at least doubled to store both the spring and summer rainfall runoff.

If an uncontrolled surface drainage system had been constructed on this quarter, design peak flows would have been at least 50% greater than pre-drainage conditions based on the reduction in storage and infiltration. Larger culverts at the road crossings, an improved ditch system downstream and some form of erosion control works or retention structure on the ravine down to Dunvegan Creek would be needed to accommodate this increase. The associated incremental off-farm costs are estimated at $6,093 for the 61.9 ha watershed area (or $98.43 per hectare of the total watershed, or $525 per hectare drained) plus any land requirement costs related to an off-farm retention facility.

Direct comparisons of the on-farm water storage costs versus the off-farm costs of uncontrolled drainage are not valid unless the full watershed is considered, and administrative, infrastructure and land costs, etc. are included in the analysis. In *Drainage Potential in Alberta* (Alberta Water Resources Commission, 1987), an evaluation of the Dunvegan Creek watershed indicated off-farm costs for uncontrolled drainage, including operating and maintenance costs, would amount to $6,491 per ha drained (this would include the $525 per hectare drained noted above).

Waterfowl Impacts: Few valid year-to-year comparisons of waterfowl numbers and production on the Olson quarter were possible due to the late initiation of waterfowl surveys in 1988 and the use of different survey designs during the three-year survey period.

A consistent increase in peak numbers of adult waterfowl, indicated breeding pairs (IBP) and brood densities was observed in the Olson quarter during the monitoring period. This likely reflects the establishment of ground cover and wetland vegetation and associated improvements in habitat quality in and around the consolidation pond since construction.

Data from the Olson quarter were compared with data from the Olson block, the nine quarter sections centred on the Olson quarter. The Olson quarter supported the highest density of breeding pairs and the highest brood production indices in the block. Although the limited data do not permit comparative analyses of habitat quality and availability and waterfowl production for the block, the relatively low values for the rest of the Olson block are probably due to poor habitat. Farming practices in the block have removed many of the natural wetlands and much of the permanent nesting cover needed by waterfowl. The Olson consolidation pond is one of the few water bodies as well as the largest permanent water body in the area, and its nesting islands and permanent cover area provide some of the few permanent nesting cover areas in the block. It seems likely that the pond is salvaging waterfowl broods from the block as well as from the area surrounding the block.

It was not possible to estimate pre-drainage waterfowl abundance and production on the Olson quarter or block because no pre-drainage waterfowl information is available and no suitable undisturbed area could be found due to extensive agricultural drainage in the region.

Nevertheless, the probable effect of farmland drainage on waterfowl production is known from other sources. For example, a recent Ducks Unlimited study in this region (T. Sankowski, pers. comm.) found that a similar but undrained area near Sexsmith had an average of 19.3 ponds/km^2 supporting 23.2 IBP/km^2, compared to 5.4 ponds/km^2 supporting 3.9 IBP/km^2 in a farmland area near Fairview. Thus, loss of wetlands resulting from slough consolidation in the area adjacent to the consolidation pond likely results in an overall net loss of waterfowl productivity.

Economic Impacts: The socio-economic assessment incorporated the following changes and additions to the preceding financial analysis:

1. a 30-year time-frame and a real 5% discount rate, plus inflation;
2. world (free market) on-farm prices and

costs assumed as 90% of the financial net farm income;
3. off-farm resource quality and/or resource use changes which are negligible under as-built conditions;
4. waterfowl-related impacts (assumed as the pond waterfowl enhancement costs of $7,383 with no benefits arising from the enhancement measures);
5. impacts on the physical (public) infrastructure, which as previously discussed are negligible;
6. inclusion of overhead costs (assumed as $1,500 as a minimum for engineering/surveying and construction supervision plus other administrative costs not identified); and
7. other benefits and costs (i.e., other environmental implications not quantified but expected to have a net negative impact).

Based on the preceding discussion on waterfowl habitat impacts and on the analysis for the Massey site (Section 3.5), it is assumed the areal loss of wetlands both in number and diversity will have a negative regional impact on waterfowl. For the purposes of this analysis, the pond habitat enhancement costs ($7,383) are added to the other costs, and no benefits from these enhancement measures are assumed.

The results of the socio-economic assessment based are summarized in Table 3.4-3.

Table 3.4-4 provides an overall evaluation summary of this project.

3.4.5 Project Conclusions

1. The consolidation pond, with the slow release line, and the backflood weir were very important components of this project because they reduced downstream flows to near pre-drainage conditions. This is especially critical because of the high erosion potential downstream of the project. The slow release line allowed drawdown of the pond which reduced the required storage capacity of the consolidation pond by half, reducing pond excavation costs, and allowed regulation of the pond levels for waterfowl habitat purposes.

2. From an agronomic perspective, the subsurface drainage system was more successful than the surface system. The subsurface system provided slightly better drainage for crop production and did not obstruct farm equipment operation. Constructing ditches in the portion of the watershed now drained by the subsurface system would have required extensive

TABLE 3.4-3. Socio-Economic Costs, Benefits and Assessment Summary, Olson Project

Costs		
On-Farm Capital Costs		$33,614
Overheads		$1,500
Waterfowl Habitat Enhancement		$7,383
	TOTAL (1985)	$42,497
Operating and Maintenance (as previously assumed)		$700/year
Benefits		
On-Farm Socio-Economic		$1,256/year
Socio-Economic Assessment		
Discount Rate		5%/year
Assessment Period		30 years
Internal Rate of Return (IRR)		-4.7%/year
Benefit/Cost (B/C) Ratio		0.39

TABLE 3.4-4. Evaluation Summary, Olson Project

Advantages	Disadvantages
1. Pre-Drainage Condition	
- Maintains at least 25 depressions totalling 14.2 ha in area for surface runoff ponding and other wetland functions. - No added drainage costs either on-farm or off-farm. - Assumed waterfowl population maintained (no monitoring to substantiate this). - Aesthetic benefit to producer of waterfowl use of wetlands.	- Average depressional wetland area of 14.2 ha remains uncultivated. - Assumed lower crop yields from 9.0 ha of transitional land around depressions (no monitoring to substantiate this). - Low field efficiency and restricted timing of operations due to depressions, with related impacts on 38.5 ha of adjacent uplands.
2. As-built Drainage and Slough Consolidation for Waterfowl	
- Increase in number of days between seeding and harvesting. - 9.5 ha of depressional land brought into production with yields at least equivalent to upland yields (and averaging 25% greater in subsurface drained areas), value equivalent to $1,006/year. - Improved field efficiency for operations of 3.3% equivalent to $111/year. - Expected increase in transition area (9 ha) yields because of improved soil conditions and reduced weed infestations (not substantiated with sample data). Assumed maximum increase of 25% equivalent to $243/year. - Assumed 1 grade improvement in crop quality on 9 ha transition area equivalent to $186/year. - Some aesthetic benefit to producer of waterfowl use of consolidation pond. - 1.7 ha consolidation pond with 1.1 ha of uplands for various wetland functions. - Off-farm hydrologic impacts are negligible.	- Capital cost of $33,614 plus $7,383 for waterfowl enhancement plus at least $1,500 for engineering etc. totalling $42,497 plus other administrative costs. - Operating and maintenance costs of $700/year estimated, expected to be an upper limit. - Need to maintain consolidation pond for waterfowl habitat. - Possible property tax increases estimated at $24/year. - Net loss of about 18 natural wetlands totalling 10.5 ha with associated wetland functions. - Potential creation of a predator trap by attracting waterfowl to an area without adequate diversity of habitat. - Farm financial B/C ratio is 0.32 and IRR is -6.1% per year. - Socio-economic B/C ratio is 0.39 and IRR is -4.7% per year.
3. Uncontrolled Surface Drainage	
- Increase in number of days between seeding and harvesting. - Some depressional land brought into production (although less than for No. 2). and additional crop yields. - Expected increase in transition area crop yields and crop quality similar to No. 2.	- Excessive cuts required to achieve drainage (not quantified). - Low field efficiency due to ditch cuts. - High erosion potential both on- and off-farm. - Off-farm runoff volumes increased 30% to 60% and peaks increased 40% to 50% as a minimum, equivalent to $6,093 for the 61.9 ha watershed (or $525 per hectare drained) plus operating and maintenance costs of 2% per year. - Loss of any waterfowl benefits derived from consolidation pond. - Net loss of 10 to 22 wetlands totalling over 12 ha in area. - Possible property tax increases as per No. 2 above. - Operating and maintenance costs of at least $250/year. - B/C and IRR not computed because this is not a realistic option.

cuts, increasing costs and erosion potential.

3. This project's net benefits are not expected to make it viable from either a farm financial or socio-economic perspective. Although crop acreage was added from over 80% of the drained depressions and the timing of operations and field efficiencies were improved, the capital, operating and maintenance costs are too high to be recouped using even the most optimistic benefits scenario.

4. The consolidation pond provides some site-specific waterfowl habitat mitigation. The data collected are insufficient to indicate how much mitigation has been achieved but it is much less than 100%.

5. The off-farm costs of an uncontrolled drainage system at this site are estimated to be $525 per hectare drained because of greatly increased peak outflows and volumes, and increased erosion potential. It is estimated that, for a larger watershed, costs of uncontrolled drainage would be in the order of $6,491 per hectare drained.

3.5 Massey Project – Slough Consolidation for Agriculture/ Waterfowl

3.5.1 Project Description

Site: The Massey site consists of a quarter section (SW-5-41-18-W4M) located approximately 25 km northeast of Stettler and 14 km east of Buffalo Lake. The site, shown on Figure 3.5-1, is in an area with an irregular pattern of hills and depressions called *knob and kettle topography*. The depressions vary in size and include some permanent wetlands. The hills range in height from 5 to 12 m; their slopes often exceed 10%, steep enough to have considerable potential for water erosion. In undrained areas, only the uplands are cultivated. Cereal crops and some forages are commonly grown in the area.

Prior to drainage, the Massey site had about 25 depressional wetland areas, occupying 13.2 ha. Runoff from the property was contained within these depressions except under extreme precipitation conditions. The depressions occupied about 20% of the quarter, and transitional areas bordering the depressions occupied about 8%. The actual area not cultivated each year varied according to meteorologic conditions, and may have ranged from 14% to 38% (9 to 25 ha) of the quarter section.

The area's native vegetation is mainly restricted to the wetland depressions and fringes where emergent vegetation and water-tolerant grasses are common. Aspen and willow typically occur as isolated stands bordering larger wetlands and on some uplands not cleared for agriculture. Many of the wetlands have been altered to some extent due to disturbance by farming operations.

The Massey site and surrounding area are considered to be ideal for waterfowl production because of the variety of wetlands found there (Jakimchuk, 1970). The area is used by large numbers of migrating geese and ducks for breeding, as well as staging during migration to and from more northerly breeding sites (Bellrose, 1976).

Objectives: to assess the on- and off-farm water management effectiveness of subsurface drainage with on-farm storage of the drained water; to evaluate the agronomic implications of the water management system; to assess the compatibility of waterfowl and agricultural land uses; and to assess the impacts of slough consolidation on waterfowl and the effectiveness of the habitat enhancement measures.

Water Management System: The water management system, completed in 1987, was designed to drain water from a 1:5 year return period, 24-hour storm event over four days. Eighteen depressions were to be drained by means of perforated subsurface tubing and Jensen inlets, and the drained water was to be stored on the quarter.

Fifteen inlets drain to a sump where the water is pumped into a large consolidation pond in the southeast corner of the quarter section (Figure 3.5-2); one inlet drains a depression to an undrained area in the northwest corner of the quarter. The use of the pump system allows drainage of the depressions even though little difference exists between the bottom elevations of many of the depressions. The system drains an estimated 10.5 ha of depressional land with another 4.1 ha of transitional land also directly affected.

The consolidation pond replaced the need for an off-farm drainage receiving system. The maximum live storage capacity of the pond is about 16,200 m^3 from the design permanent pond level (0.7 m deep) to the full supply level (1.9 m deep). Pumping into the pond is terminated when the pond reaches full supply level. When the pond water level was greater than the full supply level, it was to be lowered by using the water to irrigate upland areas.

Waterfowl Habitat Enhancement Measures: The design of the pond was to be modified to improve its value as waterfowl habitat by creating a mix of wetland types in the pond. Mitigation measures consisted of: selective clearing of deadwood and weeds, deepening and widening a connecting channel between the north and south basins of the pond, deepening a small portion of the northern basin to provide a permanent wet area, and constructing three nesting islands using excavated waste material. An existing small wooded area

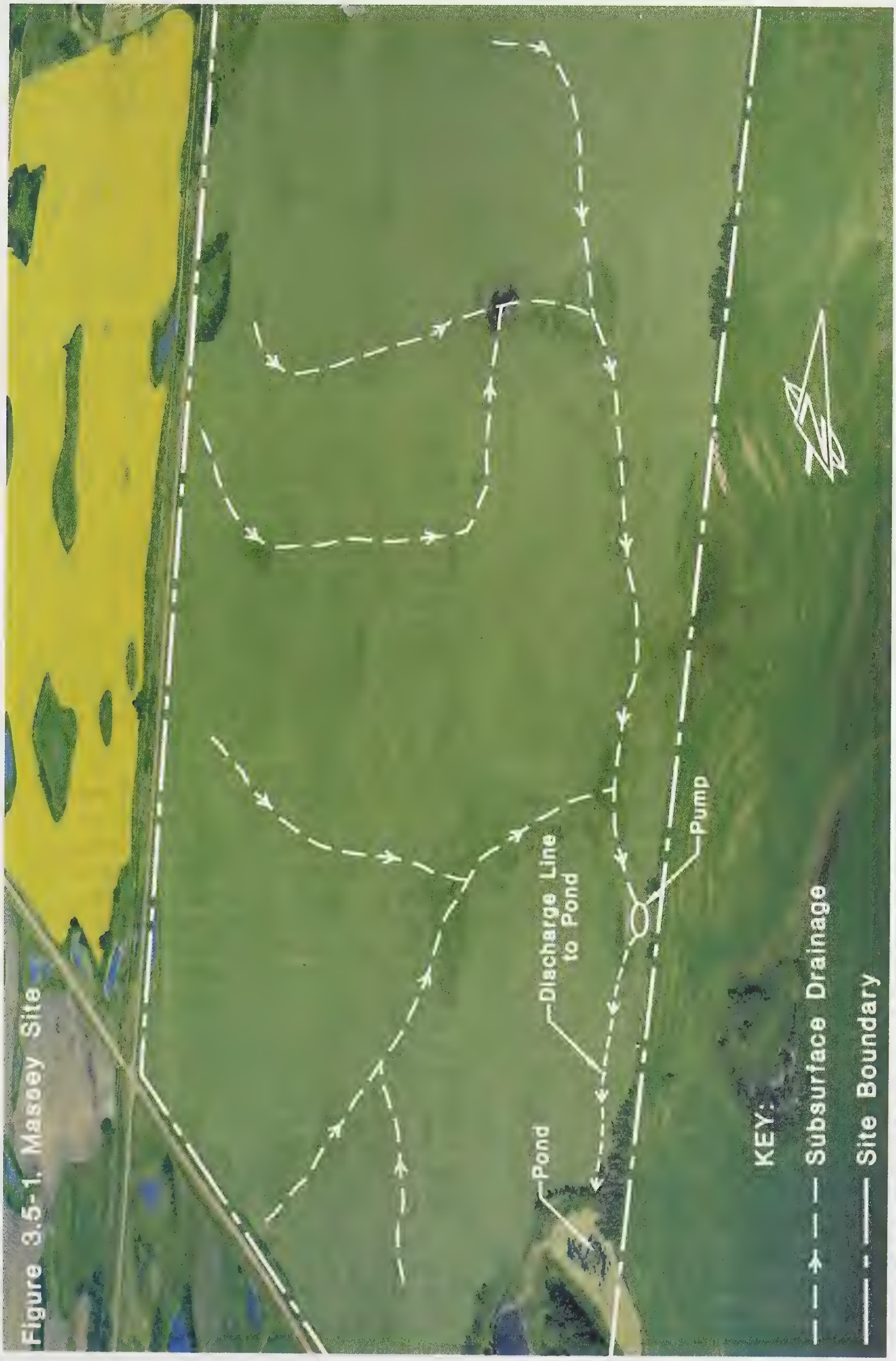

Figure 3.5-1. Massey Site

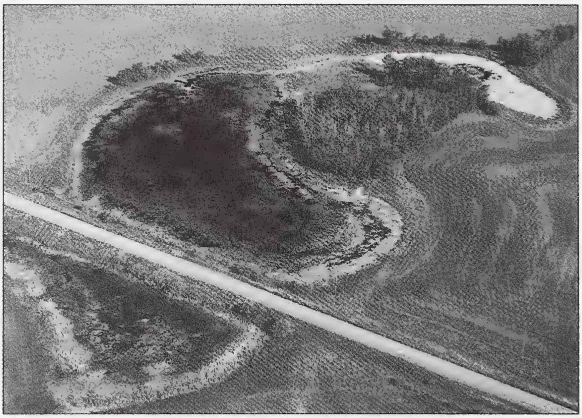

Figure 3.5-2 Massey Consolidation Pond

east of the pond also provides some possible upland habitat.

Costs: Total capital cost is estimated to be $23,773 in 1987, with about 45% contributed by the producer. This excludes costs for waterfowl enhancement of the pond at $3,850 and engineering/survey, construction supervision and equipment monitoring costs which were primarily research-related. Typical engineering costs for a similar non-research project are estimated to be about $1,500. Operating and maintenance costs for pumping (including electricity, repairs and miscellaneous expenses) average about $240/year. This excludes pumping to lower the pond level.

Data Collection: Data collection started in spring 1988 and continued to fall 1990. Runoff was monitored by measuring daily volumes pumped to the pond. Agronomic data were collected in 1989 and 1990 at two locations: an upland area not affected by the water management system (with Rego Black Chernozemic soils); and a drained depression (with Orthic Humic Gleysolic soils). Crops grown on the Massey quarter during the monitoring period were malting barley in 1988 (not sampled), canola in 1989 and wheat in 1990. A portion of canola sample was lost due to shelling out of brittle seed heads so the 1989 canola yield results are only rough estimates.

The waterfowl sampling procedure varied significantly during the monitoring period (see Section 2.3). For 1989 and 1990, the waterfowl study area for the Massey project consisted of a nine-quarter section block centred on the Massey quarter and called the Massey block. An undrained nine-quarter Comparison block, about 8 km northeast of the Massey quarter, was monitored for comparison with the Massey block. The Comparison block was selected based on similar topographic, wetland and land use characteristics; its central quarter (NW-13-41-19W4) was chosen based on its similarity (e.g., number and types of wetlands) to the pre-drainage Massey quarter.

3.5.2 Water Management System Evaluation

The as-built water management system generally works very well. It proved to be capable of pumping accumulated runoff even during very wet periods and can easily drain well in excess of a 1:10 year snowmelt event. Heavy rainfall events experienced in July 1990 exceeded the design storm event but the ponding occupied less than 2 ha and 1,000 m^3 in storage. Furthermore, most of the ponding observed was actually due to inadequate local drainage around the inlets. According to the producer, two inlets could have been better located within the depressions, but proper contouring and shaping each year should ensure adequate drainage to these inlets in the future.

The system was somewhat over-designed and could be reduced to pump 10% of a 1:5 year 72-hour storm event over four days.

The system's major limitation is the size of the consolidation pond. Assuming total seasonal pumped runoff from the site averages 45% of the regional rate, as observed from 1988 to 1990, long-term regional runoff records suggest that total seasonal pumping less evaporation would exceed the pond's maximum live storage capacity (16,200 m^3) in three out of every 20 years. Depressional back-up ponding resulting in crop losses or pumping from the pond would occur in these years as well as at the end of the season in one out of every four years on average.

The producer controlled the pond's water level by pumping excess water to a wetland area east of the pond. It would have been possible to lower the pond's level by using the water for irrigation, as originally planned, but this was not done, in part because of the high cost of sprinkler equipment.

One area where ponding persists within the drainage system is where an inlet was planned but not installed. Ponding in this area results in a crop loss of about 0.1 ha in almost all years.

The lowest drained depression in this system, which was also the monitored depression, is normally the last to drain and the hydraulic head in the system can sometimes force water from the other depressions to flow up into this depression. To accommodate this problem, the lowest depression could be seeded to grass and left uncultivated, serving as a temporary wetland. The temporary wetland would occupy only 0.25 ha and have very little impact on total crop yields or on habitat mitigation. Also the lowest depression at the Massey site is moderately saline and may, therefore, be better left under perennial cover.

Waterfowl Implications: Water levels and vegetation growth around the consolidation pond were generally not acceptable from a waterfowl habitat perspective. Although the pond's shoreline developed a typical wetland sequence with distinctive vegetation zones through the first season (1988), the northern portion of the pond was largely devoid of water that year. Also the preferred pond water levels for waterfowl were exceeded during 1990, a wet year, because of farm drainage requirements. The excessive pond levels caused flooding of the two nesting islands in the south basin and also resulted in virtually no available upland fringe around the pond for nesting waterfowl. The loss of upland habitat was exacerbated by cultivation and seeding practices which came very close to the normal shoreline of the pond because of the dry conditions in the spring/early summer of 1989. Such cultivation practices result in very little natural vegetation growth the following year and further reduce the available cover for nesting.

Other conditions which affected the waterfowl habitat at the consolidation pond were:

- reduction in the size of the nesting islands in the south basin due to slumping and erosion;
- sparse vegetation growth on the south islands; and
- slow development of extensive stands of cattail and bulrush.

The as-built water management system design could be modified to enhance the quality of wetland habitat, especially nesting and brood rearing habitat as follows.

a. *Interconnecting Channel:* The channel connecting the two basins in the consolidation pond, while deep enough to permit the free-flow of water, does not provide adequate waterfowl cover. Re-channelization to incorporate one or two S-shaped curves would create diversity in channel shape and emergent vegetation zonation, thereby providing an opportunity for increased densities of breeding ducks along the channel. A wider band of shoreline vegetation would also provide better nesting habitat. Installing a small water control structure in the channel would keep water levels in the upstream channel and northern basin of the pond higher than those present in 1988.

b. *Nesting Islands:* Grading improvements in some locations would provide a more level transition from the island to the water's edge. It is recommended that islands in smaller wetlands have a 2 m diameter flat top and a total diameter of 11 m at the normal summer water line. A mixture of coarse sands and gravel should be used to protect island shorelines from erosion. Extended resting areas should be created on the lee shores, and deep water zones should be available immediately offshore. The islands should be cleared of weeds and reseeded with an appropriate grass-legume-shrub mix.

c. *Upland Nesting Areas:* Because the Massey site has very little adjacent upland nesting habitat, the narrow margin around the pond could become a predator trap for waterfowl. As a minimum, adjacent upland nesting habitat should be at least three times the area of the consolidation wetland. Improving the existing upland vegetation to the east of the pond would involve clearing aging portions of the aspen stand to create openings for grass-shrub associations while also increasing the proportion of edge habitat. Other improvement measures include establishing a shelterbelt along the western and northwestern shoreline, limiting cultivation along the western and northwestern margins, and using reduced tillage on nearby fields.

Hydrologic Impacts: The on-farm hydrologic impacts of the Massey as-built drainage system can be summarized as follows:

1. The 10.5 ha depressional wetland area is typically fully drained by mid-April each year. It is anticipated that only 3 to 4 ha in one year out of 20 could not be cultivated due to heavy snowmelt runoff.
2. Based on the long-term statistical frequency of storm events in this area, ponding in excess of four days under current drainage conditions is expected to result in crop damages on 0.6 ha/year on average.
3. About 1 ha of nuisance ponding observed in 1990 could be eliminated with proper grading around the inlets each year. Without adequate grading this ponding may occur in about one out of every two years.

An uncontrolled surface drainage system would not be practical at this site because of the extensive ditch excavations (over 1.5 m) required and the absence of any drainage outlet. If such a system had been constructed, the depressional wetland area, minus at least 3 ha for the ditches, could have been drained in all years, but farm operations would have been severely restricted by the ditches.

3.5.3 Farm Practicality

Agronomic Evaluation: Possible agronomic benefits to the pumped drainage and slough consolidation at this site include the following:

- increased crop yields;
- improved efficiency for field operations;*
- improving timing of field operations and access to all parts of the field;*
- reduced weed control problems with increased production in transition zones;* and
- improved crop quality.

As a result of the water management system, crop acreage has increased by an estimated annual average of 9.6 ha out of the total 10.5 ha depressional wetland area.

The crop yield data are limited to observations from only two monitoring locations and one crop year. These limited data suggest depression yields were 68% of upland yields. This value is likely too low for many of the drained depressions. The monitored depression is wetter than the other depressions because it is the last to drain. It is also moderately saline, with levels sufficiently high to affect yields of some sensitive crops like canola, wheat, oats and peas. The salinity appears to be due to groundwater discharge, most likely from local sources. The smaller, higher depressions likely have lower salinity and better soil moisture conditions than the monitored depression. Also, the producer estimates depression yields are equal to or greater than upland yields. For the base case farm financial assessment, depressions yields are assumed to be 68% of upland yields; the effects of higher depression yields are tested in the sensitivity analysis.

Yields from the 4.1 ha drained transitional area have probably also increased. For the analysis below, it is assumed that pre-drainage transition area yields averaged about 70% of upland yields, and post-drainage yields would increase to 80% of upland yields.

The subsurface drainage system does not obstruct farming operations except immediately around the inlets (Figure 3.5-3). Field efficiency assessments suggest a 6.2% improvement has been realized. The producer has also found that the improved field pattern has considerably reduced overlap in field operations around irregular areas. He estimates that, as a result, there has been no change in seed, fertilizer and chemical requirements even with the addition of 9.6 ha of cultivated land. As a result, he has reduced his unit area costs for these three items.

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*Principal reasons cited by farmer for project.

Drainage of the depressions has allowed farm operations to begin earlier in the year, and access to isolated knolls is no longer restricted in wet years. The producer estimates about 1 to 1.5 hours are saved per operation in spring, and 3 to 5 hours are saved in the fall because of the drainage system.

The producer has noted a greatly reduced weed problem, particularly with respect to quack grass. Drainage has eliminated the need to periodically apply herbicides to the drained transitional areas.

The more consistent moisture conditions also allowed the producer to grow malting barley in 1988 and peas in 1991. The likelihood of producing these higher value crops would have been much lower under pre-drainage conditions.

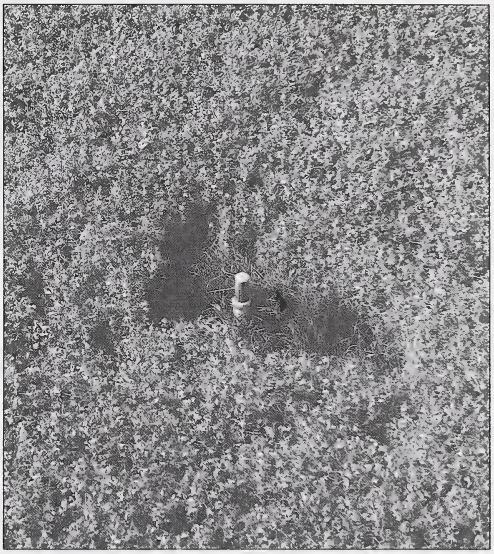


Figure 3.5-3 Jensen Inlet at the Massey Site

Financial Evaluation: The above benefits have been quantified and are summarized with the costs and results of the farm financial assessment in Table 3.5-1. Property taxes were estimated to increase by 1.13%, amounting to $6/year for the quarter section.

Although the benefits represent about a 15%

TABLE 3.5-1. Farm Costs, Benefits and Financial Assessment Summary, Massey Project

Costs		
Capital Costs (1987)		$23,773**
Operating and Maintenance* (electricity costs and pumping costs to lower the consolidation pond once in 4 years)		$290/Year
Benefits		
Additional Cropped Acreage		$197/Year
Reduced Unit Area Costs		$1,163/Year
Other Field Efficiencies		$203/Year
Property Tax Increase		($6/Year)
	TOTAL	$1,557/Year
Financial Assessment		
Commercial Interest Rate		10%/Year
Assessment Period		20 Years
Internal Rate of Return (IRR)		0.52%/Year
Benefit/Cost Ratio (B/C)		0.50

* Does not include maintenance costs required if the inlets are damaged during field operations.

** Does not include waterfowl habitat mitigation costs.

net revenue increase for this quarter section, they are not sufficient to offset the high costs.

Sensitivity tests were conducted to determine how responsive the B/C ratio and IRR are to changes in the values of the underlying parameters. The results of these tests are summarized in Table 3.5-2.

The sensitivity analysis indicates the following:
1. The wide confidence band between the upper and lower limit tests (IRR ranges from -2.3% to 13.8% per year) suggests that the existing data are not sufficiently accurate to reliably determine whether this is a good or bad drainage project from the producer's perspective.
2. When crop yield estimates for the depressions are raised to 100% of the upland yields, which may be more realistic than 68%, the B/C ratio is close to breakeven.
3. From a purely economic perspective, the existing system may be somewhat overdesigned. A smaller capacity system may marginally increase the IRR.
4. The actual cost-sharing scenario, with the base case assumptions for the benefits, suggests this project should be financially feasible for the producer.

3.5.4 Off-Farm Perspective

Hydrologic Impacts: Prior to drainage, the Massey site did not have any significant off-farm hydrologic impacts. With the as-built water management system, off-farm impacts remain minor and any off-farm drainage would be comparable to pre-drainage conditions.

Observed seepage through the road during high pond levels may cause a gradual deterioration in the road. Eventually remedial measures might consist of minor additional grading amounting to an average annual cost of about $50.

As previously mentioned, a surface drainage system at this site would not have been practical. For the design events considered in this study and generally used for drainage design in Alberta, the Massey site does not contribute to regional surface water runoff. However, runoff events greater than the 1:30 year return period may possibly result in off-farm drainage from the site. If a surface drainage system was to be constructed, it is anticipated that the runoff from the quarter would be up to three to four times greater due to reduced infiltration and evaporative losses. Surface drainage of this type of terrain would have major impacts

TABLE 3.5-2. Sensitivity Tests and Confidence Intervals, Massey Project

Variable		Simulated Change	Impact IRR (%)	Impact B/C Ratio
Base Case (100% paid by the producer; actual production data)		--	0.52	0.51
Depression Yield 100% of Upland Yield		+47%	9.1	0.95
Efficiency Cost Savings		-20%	-1.7	0.42
		+20%	2.5	0.59
Property Taxes ($60/Year) (or Increased Operating and MaintenanceCosts)		+1000%	0.1	0.49
Design Changes	Double Capacity	double	-3.1	0.36
	Half Capacity	half	0.5	0.74
Cost Sharing (with base case benefits)				
44% paid by producer (actual cost sharing)		44%	10.7	1.04
50% paid by producer		50%	8.9	0.94
75% paid by producer		75%	3.6	0.66

on the downstream conveyance system and surrounding areas, involving significant expenditures. Thus an economic analysis incorporating a system of surface drainage would show an extremely poor socio-economic investment.

Waterfowl Impacts: Statistical evaluation of waterfowl densities was not definitive due to significant differences observed between the various quarter sections in the Massey block and the Comparison block. Therefore, four methods of comparing pre- and post-consolidation conditions on waterfowl production were used, as follows:

1. Direct percentage differences in habitat suitability (HSI), habitat units (HU) and indicated breeding pairs (IBP) between the Comparison block and Massey block.
2. For the same parameters in #1 using densities from the Comparison block times the wetlands drained in the Massey quarter to define pre-consolidation conditions compared with the post-consolidation conditions observed in the Massey block;
3. Using the same approach as in #2, but applied within a square mile circle centred on the Massey quarter rather than the entire Massey block; and,
4. Using the same approach as in #2 and #3 above, but looking at only the Massey quarter.

The results of these methods are summarized in Tables 3.5-3 (for #1) and 3.5-4 (for #2, #3 and #4) for selected indicator species, diving and dabbling ducks, and total ducks using only the 1990 data (due to the changing survey methodology, year-to-year comparisons are not possible). *Dabbling ducks* (e.g., Mallard, Blue-winged Teal, Green-winged Teal and Gadwall) feed in shallow waters by tipping and by dabbling along the water's edge; they nest in upland areas. *Diving ducks* (e.g., Canvasback, Lesser Scaup and Redhead) feed by diving and are generally frequenters of the large inland water bodies. They often nest on or near the water in emergent vegetation.

These evaluations indicate a reduction in waterfowl production on the Massey quarter alone, the square mile circle centred around the Massey quarter and the entire Massey block. As expected, the impact of drainage on the drained quarter is very high (e.g., 73.8% reduction in IBP for all ducks) while the impact on the whole block of draining a single quarter is much less (e.g., 16.7% reduction in IBP for all ducks).

It should be recognized that year-to-year variations can introduce significant inconsistencies in these evaluations. For example, the IBP values recorded in 1989 (a much drier year than 1990) suggest both negative and positive differences. However, when changes in wetland areas are included, as in the case with the HSI and HU parameters, negative impacts would be expected.

Sensitivity analyses were undertaken to simulate the progressive consolidation of additional quarter sections in the Massey block. Figure 3.5-4 displays baseline conditions for the Comparison block, the Massey block without

TABLE 3.5-3. Evaluation of Waterfowl Habitat and Productivity for the Comparison Block and the Post-Consolidation Massey Block, 1990

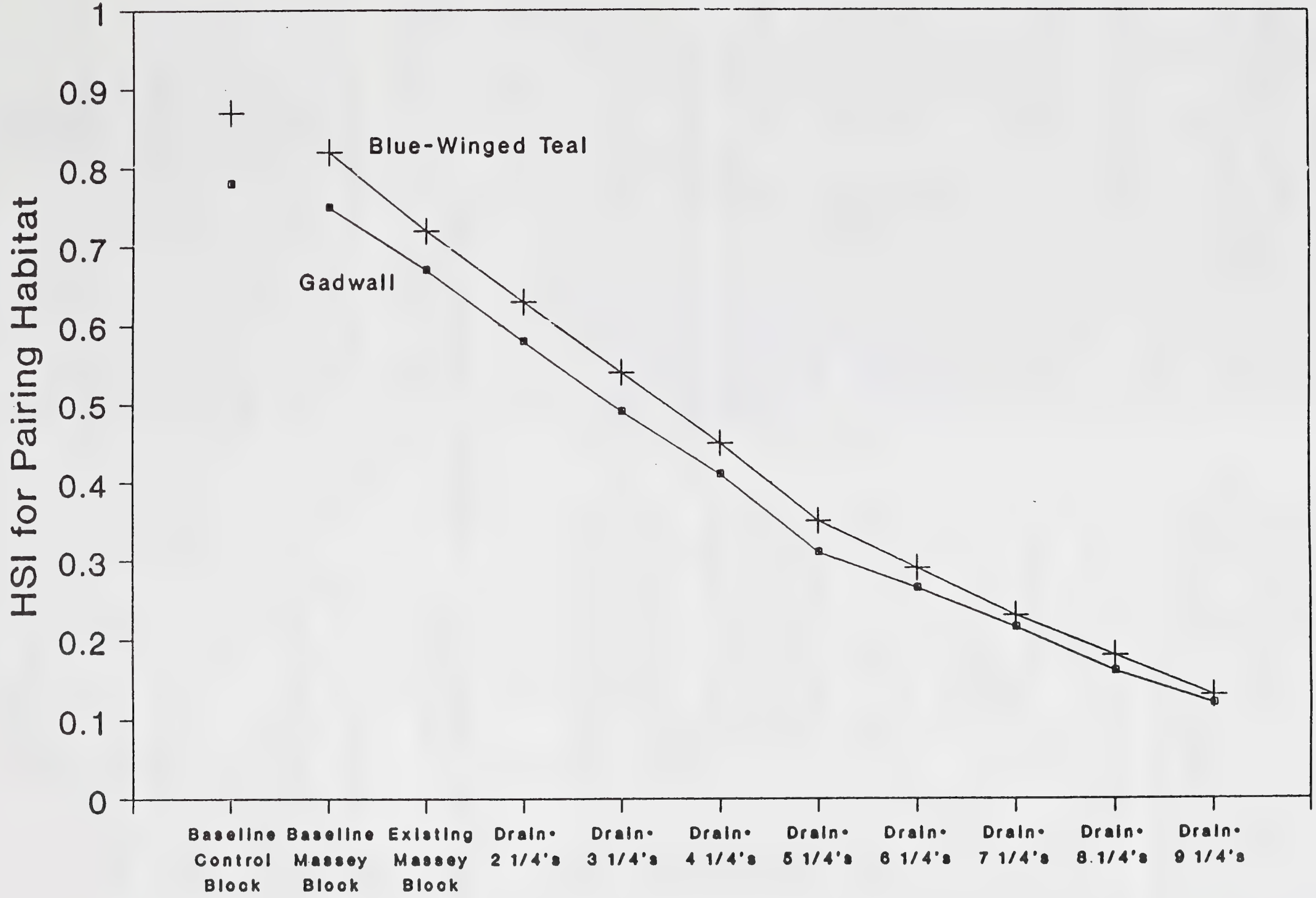
Parameter	Species	Comparison Block	Massey Block	% Difference
Habitat Suitability (HSI)	Blue-winged Teal	0.87	0.72	-17.2
	Gadwall	0.78	0.67	-14.1
Habitat Units (HU)	Blue-winged Teal	56.4	39.6	-29.8
	Gadwall	50.6	37.2	-26.5
Indicated Breeding Pairs (IBP)	Dabbling Ducks	192.1	150.3	-21.8
	Diving Ducks	37.6	38.2	+1.6
	Total Ducks	229.7	188.5	-17.9

TABLE 3.5-4. Comparison of Waterfowl Habitat and Productivity Prior To and After Wetland Consolidation, 1990, Massey Project

Parameter	Species	Change from Pre-Consolidation* to Post-Consolidation (%)
a.Massey Quarter		
Habitat Suitability (HSI)	Blue-winged Teal	-52.2
	Gadwall	-57.1
	Canvasback	-3.0
Habitat Units (HU)	Blue-winged Teal	-90.0
	Gadwall	-92.9
	Canvasback	-81.1
Indicated Breeding Pairs (IBP)	Dabbling Ducks	-76.5
	Diving Ducks	-62.6
	Total Ducks	-73.8
b. Square Mile Area Centred on theMassey Quarter		
Habitat Suitability (HSI)		
	Blue-winged Teal	-22.0
	Gadwall	-21.6
	Canvasback	-9.0
Habitat Units (HU)	Blue-winged Teal	-46.8
	Gadwall	-46.4
	Canvasback	-37.6
Indicated Breeding Pairs (IBP)	Dabbling Ducks	-31.5
	Diving Ducks	-31.5
	Total Ducks	-31.5
c. Massey Block		
Habitat Suitability (HSI)	Blue-winged Teal	-13.3
	Gadwall	-10.7
Habitat Units (HU)	Blue-winged Teal	-27.9
	Gadwall	-25.0
Indicated Breeding Pairs (IBP)	Dabbling Ducks	-17.4
	Diving Ducks	-14.0
	Total Ducks	-16.7

* As estimated, based on Comparison block densities and wetlands drained in the Massey quarter.

Figure 3.5-4 Existing Waterfowl Habitat Suitability and Implications of Wetland Consolidation on that Habitat for the Massey Study Area



Values calculated using existing consolidation data for Massey Quarter, therefore, only class II, III, and IV (temporary, seasonal and permanent) wetlands were impacted.

wetland consolidation, and the Massey block with varying amounts of wetland consolidation. The reduction in habitat suitability for Blue-winged Teal and Gadwall was basically linear with a break when about half of the area is affected. HSI values reached 0.5 on a scale of 0 to 1.0 for Gadwall and Blue-winged Teal after wetland consolidation for approximately three quarters had been simulated.

Economic Impacts: A socio-economic analysis with the following changes and additions to the financial analysis:

1. a 30-year time-frame and a real 5% discount rate, plus inflation;
2. world (free market) on-farm prices and costs assumed as 90% of the financial net farm income;
3. off-farm resource quality and/or resource use changes which are negligible under as-built conditions;
4. waterfowl-related impacts (including enhancement costs), quantified below;
5. impacts on the physical (public) infrastructure which are estimated to average about $50/year for minor additional road grading (see Section 3.5.4);
6. inclusion of overhead costs (assumed as $1,500 as a minimum for engineering/surveying and construction supervision plus other administrative costs not identified); and
7. other benefits and costs (i.e., other environmental implications, not quantified but expected to be a net negative impact). The cost of pumping to lower the pond level at least once every four years is considered to be part of the on-farm operating costs for the purposes of this assessment.

Two waterfowl-related costs are particularly important: consolidation pond enhancement costs of $3,850 and net habitat losses. A Saskatchewan study (Young and Thompson, 1990) suggests that the annual Canadian consumptive and non-consumptive wildlife-recreation costs of wetland loss may be as high as $104.90/ha. For this site, the net wetland area lost is about 8 ha (i.e., 9.6 ha drained less 1.6 ha consolidated) which would translate into about $839.20/year. Not incorporated into this value of Canadian wetlands is the value to the United States, as reflected in Ducks Unlimited and the North American Waterfowl Management Plan (1989) contributions to wetland maintenance in Canada.

The socio-economic results based on the above are summarized in Table 3.5-5.

A summary of the project evaluation is presented in Table 3.5-6.

TABLE 3.5-5. Socio-Economic Costs, Benefits and Assessment Summary, Massey Project

Costs	
On-Farm Capital Cost	$23,773
Overhead	$1,500
Waterfowl Habitat Enhancement	$3,850
Off-Farm Infrastructure	$50/Year
Lost Wetland Area	$839/Year
Benefits	
On-Farm Socio-Economic	$1,401/Year
Socio-Economic Assessment	
Discount Rate	5%/Year
Assessment Period	30 Years
Internal Rate of Return (IRR)	-7.6%/Year
Benefit/Cost (B/C) Ratio	0.45

3.5.5 Project Conclusions

1. With the as-built system, off-farm hydrologic impacts remain minor and any off-farm drainage in wet years would be comparable to pre-drainage conditions. Uncontrolled surface drainage is not practical at this site because of the extensive ditch excavations required and the absence of a drainage outlet.

2. With the as-built system, 97% of the drained depressions can now be cultivated, field efficiency has been improved, and costs per unit area for seed, chemicals and fertilizer have been reduced. The system has also increased the crop options available to the producer because of reduced variability in crop quality. The sensitivity analysis suggests that the farm financial B/C ratio may be close to breakeven.

3. The estimated net impact of the water management system on waterfowl, based on the 1990 data, is a reduction of about 74% in the total duck indicated breeding pairs on the Massey quarter and a reduction of about 17% on the Massey block. Estimated reductions in habitat units for Blue-winged Teal and Gadwall are over 90% on the quarter section, and about 25% on the Massey block.

4. The project's socio-economic B/C ratio is low, primarily because of the high costs associated with the loss of wetland habitat.

5. The as-built water management system works very well from a hydrologic perspective. The subsurface drainage system does not obstruct farm operations and adequately drains the depressions (contouring and shaping around the Jensen inlets will be an ongoing requirement to ensure good drainage). The system should be designed to pump 10% of a 1:5 year 72-hour storm event over four days. The capacity of this system is limited by the size of the consolidation pond and the lack of a controlled outlet.

TABLE 3.5-6. Evaluation Summary, Massey Project

Advantages	Disadvantages
1. Pre-Drainage Condition	
- Maintains 17 potholes, averaging 10.5 ha in area, providing habitat for waterfowl and other wildlife; capable of supporting 37.7 total duck IBP based on 1990 data. - No drainage costs on-farm or off-farm.	- An average 10.5 ha remains uncultivated (varies from 6 to 14 ha depending on meteorologic conditions). - Low field efficiency and timing of operations restricted by depressions. - Lower crop yields from an additional 4 ha transitional area, estimated at 70% of upland yields.
2. As-Built Subsurface Drainage with Slough Consolidation	
- Allows cultivation of an additional 10.2 ha on average. - Improves field efficiency by about 6.2%, equivalent to about $203/year and reduces unit area costs for seed, chemicals and fertilizer by $1,163/year. - Improves depression yields to at least 68% of upland yields on 9.6 ha on average, equivalent to about $197/year. - Improves yields 10% on 4 ha of transitional land. - Total of the above on-farm benefits is $1,563/year. - Reduces variability in crop quality, thereby increasing the crop options available to the producer. - No change in downstream drainage flood/erosion concerns. - Collects water for irrigation (though not considered economical by the producer) or other potential on-farm uses (waterfowl or stock watering). - Consolidation pond maintains 1.6 ha of wetland supporting 13.4 total duck IBP based on 1990 data.	- Initial capital cost of $23,773 plus $3,850 for waterfowl enhancement plus an estimated $1,500 for engineering design support, totalling $29,223. - Pump operations and maintenance average $240/year. - Minor additional grading required to ensure adequate drainage at inlets each year. - Minor off-farm costs associated with seepage through the road equivalent to about $50/year. - Minor flooding of the consolidation pond on the adjacent east quarter, offset by improved drainage of a depression on the border of the two quarters. - Soils in depressions remain near saturation in wet and average years reducing potential yields by 20% to 30%. - Soil salinity may be a concern in some of the larger/deeper depressions. - The capacity of the pond is expected to limit the drainage required an average of once every five years. Lowering the pond level by pumping off-farm is also expected to be necessary every fourth year on average, costing about $200 each time. - Habitat losses of the 17 depressions with the consolidation pond are estimated to result in a 73.8% decrease in total duck IBP for the Massey quarter and a 16.7% decrease for the Massey block (based on 1990 data). - The farm financial B/C ratio is 0.51 and the IRR is 0.52%/year. - The socio-economic B/C ratio is 0.45 and the IRR -7.6%/year.
3. Uncontrolled Surface Drainage	
- May increase area cultivated by about 8 ha with similar financial benefits as No. 2 above, excluding field efficiencies and reduced unit area costs. - Improves flexibility in timing of operations in the spring.	- Impractical because of excessive cuts and no available outlet. - Low field efficiency due to ditch cuts. - High erosion potential. - Increased off-farm runoff volumes and peaks. - Requires off-farm drainage system, road culverts and downstream flood control detention works. - Loss of habitat for waterfowl and other wildlife and associated wetland functions from 17 wetlands 10.5 ha in area. - High drainage costs many times greater than those for the as-built system because of need for road culvert(s) and downstream drainage system. - Loss of waterfowl benefits derived from consolidation pond.

3.6 Bredo Project – Backflooding on Peatland

3.6.1 Project Description

Site: The Bredo site is located about 10 km west of Barrhead, on the north half of Section 21-59-4-W5M (Figure 3.6-1). The site is in an area which is only partly cultivated because of extensive wetlands, including bogs and marshes.

The site consists of a relatively level area of poorly drained, organic (peat) soil about 1 m lower than the upland area in the northeast portion of the half-section. Parts of the site are covered with bush, some of which was removed in 1988. Aside from the remaining bush areas, the site was seeded to a grass-legume forage mixture and used for rotational grazing.

The watershed area within the Bredo half section is estimated at 88 ha including about 30 ha of poorly drained peat. The site also receives inflows from a watershed with a gross catchment area of 411 ha. However, permanent wetlands in the upper portion of the 411 ha watershed control the runoff from over 45% of this area. Downstream of the study site, an existing drainage ditch runs for 700 m to a large permanent slough with a natural outlet to the Paddle River.

Peat soils are highly variable with widely differing physical properties. This site has a fibrous peat that is not strongly decomposed and dries to a sponge-like material with a high moisture-retention capacity.

Objectives: to assess the impacts of peatland drainage and temporary water storage at the small watershed level; to investigate the impact of peatland drainage on farm operations and off-farm discharge rates; and to monitor soil temperature profiles and evapotranspiration to determine the effects of temporary runoff storage on soil thawing rates (reported separately).

Water Management System: The water management system has one main ditch, running from the northwest to southeast corner of the half section. The ditch was designed to lower the water table in the peat area sufficiently to allow forage and livestock production. Runoff from the surrounding area, including runoff from the upstream watershed, is stored either in a dugout or temporarily retained by backflooding on a portion of the peat area upstream of a control structure. The control structure is a berm with a stoplog control culvert near the downstream end of the main ditch (Figure 3.6-2). (A stoplog is a removable barrier which fits across the culvert opening to block the flow of water.)

The dugout was designed to be used for stock watering and supplemental irrigation. It has a storage capacity of 4,000 m^3 and is located near the midpoint of the ditch. A round hay bale is used to block the ditch and direct water into the dugout.

Backflooding was included in the project because lowering the water table in peat typically causes the peat to become too dry for good plant growth. Like choked drainage, backflooding allows water to infiltrate the soil, and reduces peak outflows and volumes. In contrast to choked drainage, where discharge is controlled by the choke size, in backflooding the landowner controls when the water is released.

The backflood control structure at the Bredo site was designed to allow up to 17,000 m^3 of temporary storage over an area of 5 ha. The backflood berm was sized to provide a ditch crossing for farm equipment. An emergency spillway channel excavated around the berm limits backflooding above the regulated backflood depth.

Costs: The constructed capital costs in 1987 and 1988 are estimated to be $18,828, with about 29% paid by the landowner. Pasture improvement costs also included about $5,000 for fencing in 1988, and about $1,070 for pasture reseeding in 1986 and 1990. Operating and maintenance costs are minor and include electric fencing at about $100/year plus some irrigation costs.

Data Collection: Full data collection at the Bredo site started in fall 1988 and continued to fall 1990. Agronomic data were collected at four locations as follows: two backflooded peat soil locations (with Terric Mesisols), a drained

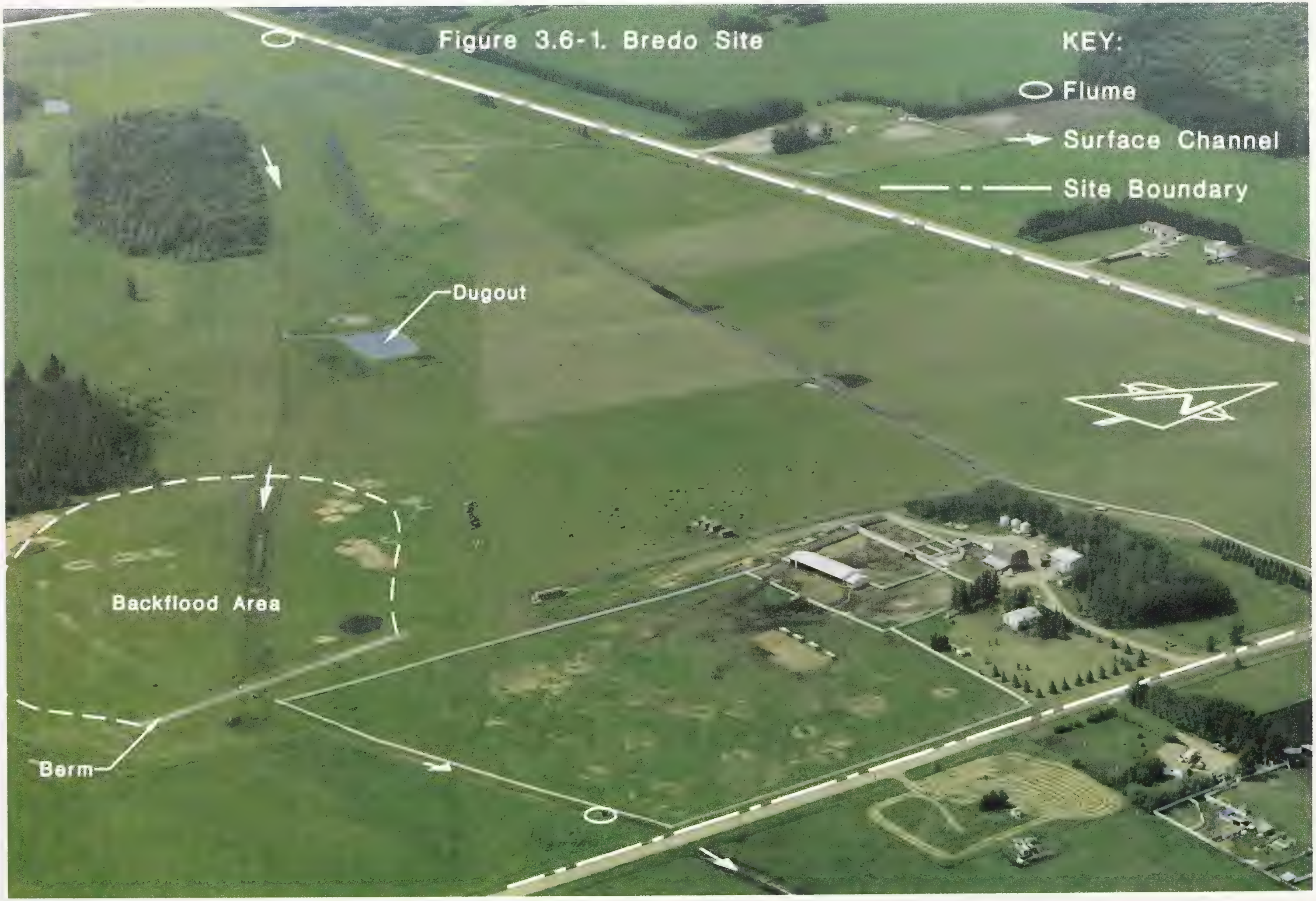


Figure 3.6-1. Bredo Site

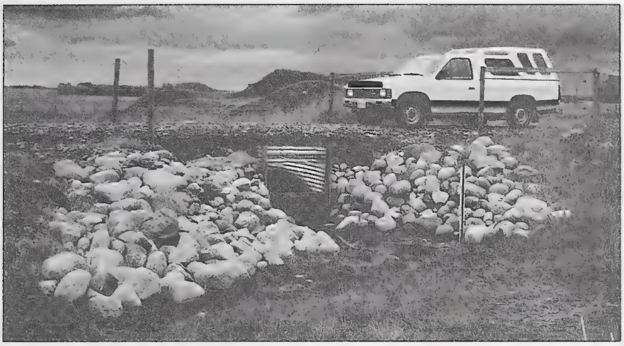


Figure 3.6-2 Backflood Structure at the Bredo Site

peat soil (with Terric Mesisols), and an upland location not affected by the water management system (with Dark Gray Luvisols).

3.6.2 Water Management System Evaluation

During the monitoring period, the maximum backflood storage was about 2,000 m^3, which disappeared in a couple of days due to infiltration into the peat. Adequate storage was maintained in the 4,000 m^3 dugout to provide for water for cattle and irrigation.

The original design criteria were based on snowmelt runoff because rainfall runoff is not large enough at this site to be significant for design purposes. The average spring runoff volume was originally estimated at 116,000 m^3 based on the assumption that site spring runoff was 65% of the regional spring runoff. However, observations suggest that spring site runoff volume amounts to about 41,000 m^3 or about 20% of the regional value because of upstream depressional storage and absorption of runoff by the peat soils.

The peat at this site has a high moisture-holding capacity and consequently backflooding and dugout storage can significantly reduce runoff volumes. For example, the 1990 spring runoff downstream of the project would have been at least 25% greater without backflood storage.

During average runoff conditions, the maximum backflood storage available (17,000 m^3) is over 40% of the revised average spring runoff volume (41,000 m^3). Adding the dugout storage increases this to over 50%. During above average spring runoff years, the ground is likely to be frozen and the impact of the water management system is expected to be minimal compared to pre-drainage conditions when water flooded over the entire peatland area. Severe flood peak flows under as-built conditions are, therefore, expected to be very similar to such flows under pre-drainage conditions. It also appears that the minor amount of rainfall runoff experienced on this watershed can easily be retained by the backflood control structure.

Because all backflooded water was absorbed by the peat, this project did not achieve a full backflood in the commonly used sense of the term (i.e., in a typical backflood, some surface water remains after backflooding for release into the downstream watercourse).

The design concept could be modified to reduce the size of the backflood control structure outlet so that it is capable of draining the maximum backflood storage in four days (reducing the average design flow from the 1.35 m^3/s used to 0.05 m^3/s). During greater runoff events, excess runoff would drain around the berm through the spillway channel. Erosion concerns are probably lower with this modification as opposed to concentrating the entire flow through the outlet structure. As well, the reduced size of the control structure would have reduced construction costs by about $1,150.

Another modification, suggested by the producer, was to locate the dugout closer to the backflood structure to reduce earthmoving costs for the berm. However, the as-built dugout is located in a natural low area which minimizes construction costs. Also, the as-built storage system, with two separate storage areas, is probably preferable for rotational grazing purposes.

Hydrologic Impacts: The observations from this project cannot be generally applied to other peatland sites. Peat characteristics vary greatly from place to place, and these variations significantly influence the nature and magnitude of the hydrologic impacts from the drainage.

The site-specific hydrologic impacts of this project can be summarized as follows:

1. The drainage ditch adequately removes excess water in the spring from the Bredo peatland area. The producer estimates about 12 ha out of the 30 ha of peatland have been directly affected.
2. The long-term average area directly affected by backflooding is estimated to be about 3.5 ha.
3. Spring runoff volumes are expected to be adequate to fill the dugout in 19 years out of 20, ensuring a water supply for stock and supplemental irrigation.
4. The drainage ditch obstructs farm equipment operation and requires weed control, but this disadvantage is at least partially offset because the backflood berm provides a farm crossing.

3.6.3 Farm Practicality

Agronomic Evaluation: Possible agronomic benefits of the drainage and backflood works constructed at this site include the following:

- increased acreage for forage production;
- increased forage production on backflooded areas;
- provision of a supplemental water supply for livestock and irrigation; and
- implementation of a rotational grazing program and increased livestock carrying capacity.*

The drainage ditch gradually increased the total area under forages by about 12 ha. The yields from the drained area averaged about 80% of the yields from the upland area in 1989 and 1990, possibly because the drained area was only recently cultivated for the first time.

The pasture improvements in the 12 ha consisted of developing the area in approximately two equal parts. The first 6 ha were seeded in 1986, harvested in 1987 and 1988, and then used as mature pasture from 1989 onwards. The other 6 ha were seeded in 1990, used as fall pasture in 1991, and as mature pasture from 1992 onwards.

The data suggest that increased soil moisture from backflooding increased yields from the 3.5 ha backflooded area; a longer monitoring period would be needed to clarify this. The data were insufficient to indicate if backflooding affected soil temperatures.

Forage quality may have been affected slightly by the water management system but the data are inconsistent.

Annual spring runoff is expected to be adequate in almost all years to fill the 4,000 m^3 dugout. The producer determined that supplemental irrigation with water from the dugout resulted in a very small net benefit and therefore regular irrigation was not warranted. Thus the dugout is used only for stock watering.

The end result of the above benefits has been an increase in livestock carrying capacity.

Financial Evaluation: Based on pasture improvements taking place over several years (as described above), grass seeding and harvest costs were calculated along with revenues from increased forage and livestock production. Despite the productivity increases, information provided by a registered appraiser suggests no property tax increases are anticipated with this project.

The project's benefits and the costs and the results of the farm financial analysis (which assumes the producer paid 100% of the costs) are summarized in Table 3.6-1.

This base case comparison strongly suggests that, with full costing, this project would not likely be a feasible investment opportunity.

Sensitivity tests conducted to illustrate potential variations in the B/C ratio and the IRR assume the following conditions:

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*Principal reasons cited by the producer for this project.

TABLE 3.6-1. Farm Costs, Benefits and Financial Assessment Summary, Bredo Project

Costs*		
1986 Seeding (6 ha)		$1,070
1987 Ditch and Dugout Earthworks		$8,695
1987 Harvesting (6 ha)		$720
1988 Dyke/Structure/Miscellaneous		$10,134
1988 Pasture Fencing		$5,000
1988 Harvesting (6 ha)		$720
1990 Seeding (6 ha)		$1,070
	TOTAL	$27,409
Operating and Maintenance (electric fencing, 1989 on)		$100/Year
Benefits		
Gross Forage Revenue (6 ha)		$2,045/Year (1987 & 1988 only)
Livestock Productivity Increase**		$803/Year
Backflooding Crop Yield Increase (starting in 1989)		$173/Year
Financial Assessment		
Commercial Interest Rate		10% per Year
Assessment Period		20 Years
Full Costing Internal Rate of Return (IRR)		-4.88% per Year
Benefit/Cost (B/C) Ratio		0.39

* Engineering design and supervision costs are not included.

** Assuming 50% of benefits were achieved in 1989 and 1990, 75% achieved in 1991, and 100% achieved thereafter.

1. a 20% change in the total annual revenue projections; and
2. the ramifications of various cost-sharing arrangements or, alternatively, reductions in the total capital project costs on a percentage basis.

These calculations are summarized in Table 3.6-2.

These sensitivities illustrate how small errors in the underlying database can greatly affect the bottom line. Again, there is a 1:1 relationship between percentage changes to the projected revenue stream and percentage changes to the resulting B/C ratios.

3.6.4 Off-Farm Perspective

Environmental Impacts: No increases in peak flows or volumes over pre-drainage conditions are anticipated because of the project's backflood and dugout storage. Hence, off-farm hydrologic impacts are negligible.

With an uncontrolled drainage system, 1:10 year and 1:25 year design peak outflows from the Bredo site would be expected to increase about 50%. These are physically minor increases which the downstream culvert and ditch system can easily accommodate. However, applying this order of magnitude increase in flow to the entire watershed draining into the large permanent slough downstream of the Bredo site, the corresponding off-farm infrastructure cost of the Bredo project is estimated to be $2,160. A portion of this incremental cost includes provision for an outlet control structure on the permanent slough to reduce peak outflows into the channel draining to the Paddle River.

Other factors potentially affected by the water management system at this site, such as groundwater conditions and wildlife densities and habitat, were not monitored. A minor net negative cumulative impact would be anticipated on these and other wetland functions.

Economic Impacts: A socio-economic assessment was conducted with the following addi-

TABLE 3.6-2. Sensitivity Tests and Confidence Tests, Bredo Project

Variable	Simulated Change	Impact IRR (%)	Impact B/C Ratio
Base Case (100% paid by producer; actual production data)	--	-4.88%	0.39
Upper Limit			
Projected Monetary Benefits Increase 20%	+20%	-2.73%	0.46
Lower Limit			
Projected Monetary Benefits Decrease 20%	-20%	-7.30%	0.31
Cost Sharing (with base case benefits)			
29% paid by producer (actual cost sharing)	29%	3.60	0.74
50% paid by producer	50%	0	0.58
70% paid by producer	70%	-2.86	0.46

tions and changes to the financial analysis:

1. a 30-year time-frame and a real 5% discount rate, plus inflation;
2. world (free market) on-farm prices and costs (no financial price adjustments are used for this analysis since beef operations are already in an essentially free market situation);
3. off-farm resource quality and/or resource use changes which, as previously discussed, are negligible under as-built conditions;
4. wildlife-related impacts including enhancement costs (assumed as no net change for this analysis);
5. impacts on the physical (public) infrastructure (none identified);
6. inclusion of overhead costs (assumed as $1,500 as a minimum for engineering/surveying and construction supervision plus other administrative costs not identified); and
7. other benefits and costs (i.e., other environmental implications, not quantified but expected to be a net negative impact).

The socio-economic assessment results based on the above are summarized in Table 3.6-3.

TABLE 3.6-3. Socio-Economic Costs, Benefits and Assessment Summary, Bredo Project

Costs	
Capital Costs (as per Table 3.6-1)	$27,409
Overheads	$1,500
Annual Operating and Maintenance	$100/Year
Benefits	
Gross Forage Revenue	$2,045/Year (1987 & 1988 only)
Livestock Productivity Increase (as per Table 3.6-1)	$803/Year
Backflooding Yield Increase (1989 on)	$173/Year
Socio-Economic Assessment	
Discount Rate	5% per Year
Assessment Period	30 Years
Internal Rate of Return (IRR)	-0.6% per Year
Benefit/Cost (B/C) Ratio	0.57

The project evaluation is summarized in Table 3.6-4.

3.6.5 Project Conclusions

1. The drainage ditches, dugout storage and backflooding provided at this site in combination with pasture seeding and pasture fencing have increased the acreage available for forage production, improved field efficiency, provided a reliable source of water for livestock and increased livestock carrying capacity. The backflooding storage has reduced runoff volumes and peaks to values equal to or below pre-drainage values, and increased forage yields.

2. This project was not a full backflood in the commonly used sense of the term because all backflooded water was absorbed by the peat. The runoff estimates used to design this project should be significantly reduced to take into account the high water retention capacity of the peat and the upstream depressional storage in this watershed. The highly variable characteristics of peat limit direct application of these observations to other peatland areas.

3. The farm financial and socio-economic B/C ratios are well below breakeven because of the project's high capital costs. A more cost-effective design would improve the B/C ratios but they would still not reach breakeven.

TABLE 3.6-4. Evaluation Summary, Bredo Project

Advantages	Disadvantages
1. Pre-Drainage Conditions	
- Maintains 30 ha peatland area for runoff regulation and other natural functions. - No added drainage costs either on-farm or off-farm.	- Depressed yield from 30 ha peatland area (no pre-drainage yield data). - Saturated peatland area restricting farm operations. - Unregulated flooding and runoff over peatland area.
2. As-Built Surface Drainage with Backflood Control and Dugout	
- Dependable water supply source centrally located. - Improved pasture on 12 ha of peatland capable of providing 76 AUM equivalent to $803/Year. - Improved forage yields on 3.5 ha of backflood area equivalent to $173/Year. - Regulated runoff control and improved drainage for farm operations (e.g., for cattle accessibility). - No change in off-farm hydrologic impacts. - No property tax change expected.	- Capital cost of $27,409 plus operating and maintenance costs of $100/Year plus engineering design and support costs. - Need to manage water, control backflooding and fill dugout (a minor management concern with this design). - Change in natural function of at least 12 ha of peatland area (a minor consideration for a pasture operation). - Minor amount of backflooding to date. - Drainage ditch provides a minor restriction to farm operations. - Farm financial B/C ratio is 0.39 and IRR is -4.88% /Year. - Socio-economic B/C ratio is 0.57 and IRR is -0.6%/Year.
3. Uncontrolled Drainage	
- Improved pasture on 12 ha of peatland capable of providing 76 AUM equivalent to $803/Year. - Improved drainage for farm operations.	- No improvement in water supply unless dugout provided. - Drainage ditch restrictions to farm operations. - Capital cost of No. 2 above reduced to $17,660 with dugout. - 50% increase in downstream flood peaks costing $2,160 ($24.55/ha) for the 88 ha drained plus operation and maintenance costs of 2% per year ($43.20/Year).

4.0 Conclusions

4.1 Hydrology

1. **Uncontrolled drainage at the six sites would have increased off-farm peak flows by an estimated 15% to over 200% of pre-drainage levels. In comparison, the five controlled drainage methods effectively reduced off-farm peak flows to near pre-drainage flows.**

   Uncontrolled drainage is the least expensive drainage method for a producer to construct and is the method preferred by most producers. However, the increases in off-farm peak flows due to uncontrolled drainage often result in downstream flooding, erosion and sedimentation unless expensive controls are installed.

2. **Post-construction on-farm water retention must be nearly equal to pre-drainage storage volumes to prevent off-farm peak flows from significantly exceeding pre-drainage levels.**

   Under natural conditions, each wetland will retain a certain volume of water before overflowing into adjacent wetlands and eventually flowing off the farm. As wetlands are linked together with surface ditches, this natural storage is removed.

   The controls installed for the surface drained choke, backflood and consolidation alternatives tested in this study provide near pre-drainage control of off-farm peak flows based on the 1:10 year rainfall event. However, for greater than 1:10 year rainfall events, the pre-drainage flows would be exceeded in some instances (depending on the watershed topography), which could result in serious downstream impacts.

   To guarantee that pre-drainage off-farm peak flows from a surface drainage system are never exceeded would require increased construction costs in many instances. In some cases a control structure would have to be installed on each depressional area to ensure that the natural drainage configuration is maintained; in other instances, pre-drainage total storage could be maintained by increasing the size of berms used to retain the runoff.

3. **All farm water management systems must be properly designed and constructed by qualified personnel and regularly maintained to ensure that the systems operate effectively, without causing adverse on- and off-farm impacts.**

   Properly designed systems can include simple, low-cost control structures with minimal operational and maintenance requirements, which are preferable from a farm financial perspective.

4. **Farm water management designs based on draining a 1:10 year rainfall event over 48 hours will ensure that excess rainfall is removed before serious crop damage occurs and snowmelt is usually removed in time for normal spring work to proceed over the whole field.**

   Farm water management designs are typically based on 5 to 10 year return period flood events. Producers are willing to accept some crop damage resulting from larger flood events, given the significantly higher costs to design and construct systems to handle greater than 1:10 year flood events.

5. **When calculating runoff volumes for hydrologic design, the commonly used SCS method generally provides good estimates for the central and Peace River regions of Alberta.**

   The relatively large volume of watershed storage and the long periods between significant rainfall events throughout most of Alberta indicate that 48- to 72-hour duration rainfall events, with Curve Number (CN) values based on dry conditions before the event, should be used for design of farm water management projects.

6. **When calculating peak flows for hydrologic design, standard empirical hydrologic formulas will significantly overestimate these flows on small watersheds unless appropriately adjusted to account for the effects of storage.**

   Most watersheds in Alberta's central and Peace River regions have a large amount of depressional storage and, therefore, high soil moisture infiltration. As a result, peak flows will be delayed and reduced to values lower than those estimated by standard methods. For instance, runoff response to rainfall in these areas is typically insignificant for precipitation events less than 20 to 40 mm.

   As a result, the design capacity of control structures for farm water management in small watersheds may be somewhat reduced over current practices, which will save construction costs. Reducing design capacity would also have the added advantage of further reducing downstream peak flows.

7. **Defining the contributing watershed area is critically important in the design of small watershed systems.**

   The contributing watershed area is used to determine the size of water conveyance and control structures. However, the contributing area can be difficult to delineate if watershed relief is low and no well-defined watercourses occur. In such circumstances, the contributing watershed area can vary greatly, making design of an effective water management system very difficult. Pre-construction flow monitoring may help to better define the contributing area.

   Also, on flat, farm-size watersheds, typically less than 60 to 120 ha in size, peak runoff events are frequently controlled in part by flow obstructions, like ice or snow blockages in ditches, rather than by the hydrologic conditions used to design the water management system.

8. **The use of subsurface tubing for removal of excess water is preferable to surface drainage in terms of the off-farm hydrology.**

   Subsurface drainage, while more expensive than surface drainage, provides better hydrologic control. The diameter of the tubing defines the peak flow from the drainage system, which allows for more accurate design of the downstream receiving channels. When rainfall events exceed the design rainfall event, excess water will simply remain within the drained depressional areas for a longer period of time. This may affect the farmer's operations and crop yields, but will not affect the off-farm drainage system beyond the impacts of the original design.

9. **Surface ditches tend to remain wet throughout much of the growing season if there are very low ditch slopes, upslope seepage and/or surface disturbance from crossing of farm machinery.**

   Wet ditches cannot be cultivated or crossed by farm equipment. Permanently grassing these ditches appears to be a good management alternative because the grass will protect the ditches from erosion and may be harvested for forage when conditions permit.

10. **Where ditch cuts exceed 0.3 m, it is impractical to construct ditch side slopes low enough to allow farm machinery to cross.**

    In this situation, the 10:1 side slope needed to allow crossing requires the excavation and disposal of very large volumes of soil. Steeper side slopes (4:1) are recommended, which will result in narrower ditches and less excavation. However, farming operations will be obstructed to a greater degree.

12. **Construction of a pond is most cost-effective when excavated material from the pond is used to build a berm to increase the pond's storage capacity.**

    The deeper a pond or dugout is excavated, the higher the cost of excavation becomes. Reducing the excavation depth and using the excavated material to construct a berm will provide the same storage capacity for considerably less capital cost. However, to achieve water storage above that provided by gravity drainage requires some form of pumping which can range from $200 to $500 annually in operation and maintenance costs, in addition to the initial capital cost.

4.2 Agronomy

The strength of the agronomic conclusions is affected by data limitations. For all sites, the monitoring periods were too short to encompass the full range of likely agronomic conditions. With the exception of the Olson project, the data were collected too soon after project construction to account for disturbance from construction, dewatering and subsequent changes in farm operations. Pre-drainage data, data over an entire field, and weed control data would have helped to more clearly define the effects on crop yields, crop quality and weed control. Some of the agronomic conclusions are based on the cooperating producer's non-quantitative observations.

1. **The controlled drainage projects resulted in a net increase in the acreage available for crop production without detrimental hydrologic impacts downstream.**

   By bringing additional land into production, the producers intensified the use of their existing land base.

2. **The sites with subsurface water management systems performed better in terms of yields and weed control than the sites with field ditches.**

   The drained depressions at the sites with subsurface systems produced yields close to upland yields and weed control problems were significantly reduced. The sites with field ditches had less effective drainage and poorer yields from the drained depressions. In some cases, the ditches remained conveyors of water rather than producers of crops.

3. **The Massey site's subsurface drainage system resulted in more consistent soil moisture conditions and, consequently, less variability in crop quality, allowing the producer to increase his cropping choices.**

   Flexibility in cropping choices allows a producer to be more market responsive, that is, to grow crops which are currently of higher value. For some crops, consistent crop quality is very important factor in saleability and price. After project construction, Mr. Massey was able to grow malting barley and peas, two higher value crops which require consistent crop quality.

4. **Temporarily retaining water on fibrous, sponge-like peat improved forage yields.**

   Further monitoring would be needed to confirm this result.

5. **Farm water management techniques which include consolidation of temporary wetlands as a means of on-farm water storage provide needed water for domestic and livestock use.**

   Most of Alberta has a moisture deficit for at least part of the growing season, which may limit water supply for domestic and livestock use. Uncontrolled drainage of temporary wetlands removes potentially usable water from the farm. During dry years, this loss of water can be costly since there is often the need to pump water to farmsteads from permanent water sources. A secure farm water supply is especially critical for reducing the risk of livestock production losses due to drought.

   Although this is a valuable benefit, other water management options would provide this same benefit without requiring wetland drainage. For example, existing permanent wetlands could be deepened or new farm dugouts could be excavated.

6. **Field ditches result in lower field efficiency than subsurface drainage when the ditches remain wet or if the ditches are too deep to be crossed easily by field equipment.**

For most producers, field efficiency is a key objective for their farm water management system. Subsurface systems offered almost no obstacles to field operations. At most of the surface drainage sites, some or all of the ditches could not be cropped or driven through during the monitoring period.

Forages are generally more tolerant of ponding than cereal crops and are less affected by the critical timing of operations such as spring seeding. Thus ditches, which are less costly than subsurface drainage, can work effectively in hay and pasture production.

4.3 Waterfowl

The strength of the waterfowl-related conclusions is somewhat limited because of changes in the data collection methodology, the absence of pre-drainage data and the lack of a comparable undrained area near the Olson site.

1. **Drainage of temporary and permanent depressional wetlands causes a reduction in habitat available for waterfowl breeding, nesting and brood rearing and, therefore, will cause a reduction in overall populations.**

   Any form of wetland drainage will be detrimental to the North American Waterfowl Management Plan's goal of increasing waterfowl populations to the levels achieved in the 1970s.

   This study evaluated the impacts of drainage on waterfowl only. Many other species of birds, mammals, amphibians, reptiles and plants also require wetlands for some portion of their life cycles and therefore would also be harmed by drainage.

2. **Consolidation of all or a portion of the drained water into one pond with some habitat enhancement provides only limited mitigation of waterfowl losses.**

   Wetland consolidation with pond habitat enhancement and minimal upland habitat can provide some brood salvage habitat in an area where permanent water is limited because of drainage and/or drought, and then only if nesting habitat is available within 2 to 4 km of the pond.

   The impact on waterfowl productivity of draining a quarter section is strongly negative for the drained quarter itself. For example, based on the 1990 data, the estimated numbers of dabbling and diving duck breeding pairs on the Massey quarter declined 77% and 63%, respectively, as a result of wetland consolidation. The loss of habitat units averaged 91% for two representative dabbling duck species (Gadwall and Blue-winged Teal) and 81% for a diving duck species (Canvasback). These numbers are consistent with the 80% loss of waterfowl associated with total drainage of non-permanent wetlands determined previously (Alberta Water Resources Commission, 1987).

   The impact on waterfowl productivity of draining a single quarter section within an undrained nine-quarter section block is much less pronounced, but the impact increases as the number of drained quarter sections increases.

4.4 Economics

1. **As constructed, none of the projects were financially viable, assuming the producers paid 100% of the costs.**

   With no government cost-sharing, Benefit/Cost ratios ranged from about 0.2 to 0.5 (Table 4.4-1). Even with actual government cost-sharing, which ranged from 55% to over 75% of the total project costs, only one project was financially viable. These low ratios were not primarily the result of poor crop prices: crop prices used in the analysis were based on 15-year averages (1976/77 to 1990/91), which included some relatively high prices.

   The financial analysis included the following sensitivities: ±20% changes in total

TABLE 4.4-1. Farm Financial Benefit/Cost Ratios for the Five Controlled Drainage Projects

Project	Actual B/C Ratio	B/C Ratio Based on Optimistic Benefits
Glasier	0.17	0.51
Sipma	0.47	0.56
Olson	0.32	0.38
Massey	0.50	0.95
Bredo	0.39	0.46

annual revenue projections, increased crop yields and/or crop quality in the drained depressions, revised construction costs based on design changes, changes in farm efficiencies, and a lowering of the interest rate from 10% to 5%. Of all the projects, the Massey project comes closest to reaching the breakeven point using these sensitivity tests. If the crop yields from the drained depressions on the Massey site are assumed to be, on average, equal (based on the producer's estimates) to the upland yields, then the project's B/C ratio becomes 0.95.

For the other projects, none of the sensitivities improved the financial returns to a breakeven level. Only by combining the most optimistic net revenue streams with the actual cost-sharing arrangements did the Benefit/Cost ratios and Internal Rates of Return increase to near or above the breakeven point for some of the projects.

While these pilot projects were cost-shared and various levels of cost-sharing were included in the sensitivity analysis, almost no government assistance is now available for such on-farm water management projects. At present, the only cost-sharing available is through the Prairie Farm Rehabilitation Administration (PFRA) for dugout construction.

As noted in Section 4.1, the design capacities could have been reduced for some of the projects, thereby lowering construction costs. This would have increased the Benefit/Cost ratios, although probably not enough to reach breakeven. For example, for the Massey project, design capacity was doubled and halved in the sensitivity analysis (Table 3.5-2), giving Benefit/Cost ratios of 0.36 and 0.74, respectively. For the Glasier project, least-cost design and construction (see Section 3.2.3) still did not result in a breakeven Benefit/Cost ratio.

2. **The results of the farm financial analysis reinforce the contention that non-financial factors also influence producers' decisions regarding farm water management.**

For some producers, removal of the inconvenience of getting stuck and working around many small wetlands is worth the expense of drainage. Producers may also see an opportunity to reduce risk by implementing on-farm water management. For example, dugout storage at the Sipma site decreased the risk of water shortages, allowing the producer to increase livestock carrying capacity. As well, the Massey water management system enabled the producer to expand his cropping choices to include malting barley and field peas.

While tax incentives generally influence management decisions, they are unlikely to have much influence in these situations. Few farmers have sufficiently high taxable incomes that they would implement a water management project on the basis that the cost could be written off. Similarly, Alberta's property tax assessment policy is not likely to encourage drainage. In fact it may be a deterrent: wetlands are assessed at a very low rate and wetland drainage may result in a higher assessment and taxes, not only on the acres converted to crop land but on the entire quarter if all or most of the "inconvenience" is removed from the quarter.

3. **The projects were not viable from a socio-economic perspective.**

The socio-economic Benefit/Cost ratios ranged from approximately 0.1 to 0.8 (Table 4.4-2). The major socio-economic

TABLE 4.4-2. Socio-Economic Benefit/Cost Ratios for the Controlled Drainage Projects

Project	B/C Ratio
Glasier	0.12
Sipma	0.78
Olson	0.39
Massey	0.45
Bredo	0.57

impacts of drainage were from off-farm flooding, erosion and/or loss of waterfowl production. Without the water control structures for these projects, off-farm flooding and erosion would have been significantly greater.

The two sites with forage/livestock systems had the lowest calculated off-farm impacts. This stands to reason since land in forage production, whether for hay or pasture, is less prone to erosion, often does not need as much drainage, and generally provides better wildlife cover in comparison to land in annual crop production.

Although the Massey project worked well from the hydrologic and agronomic perspectives, and may be financially viable, the waterfowl habitat mitigation effort was relatively unsuccessful from a socio-economic perspective. Mitigation of the consolidation pond was expensive and wetland drainage resulted in loss of the different types of wetlands needed by waterfowl and a significant net reduction in the number of waterfowl produced on the quarter.

4.5 Overall Conclusions

This section brings together and summarizes the above conclusions.

1. **The controlled water management alternatives examined in this study were all successful in maintaining near pre-drainage flows.**

   Maintaining pre-drainage flow conditions is essential to avoid off-farm flow increases which could increase downstream erosion, flooding, sedimentation and water quality deterioration, or increase infrastructure costs.

2. **Uncontrolled drainage results in significant increases in off-farm peak flows which can cause serious negative impacts such as erosion, flooding, sedimentation and water quality deterioration, as well as costly remediation.**

3. **Farm water management techniques which include consolidation of temporary wetlands as a means of on-farm water storage can provide needed water for domestic and livestock use.**

   Most of Alberta has a moisture deficit for at least part of the growing season which may limit the water supply for domestic and livestock use. A secure farm water supply is especially critical for reducing the risk of cattle production losses due to drought.

   Although this is a valuable benefit, other water management options would provide this same benefit without requiring wetland drainage. For example, existing permanent wetlands could be deepened or new farm dugouts could be excavated.

4. **The controlled water management alternatives all achieved some agronomic benefits, although the benefits were very small in some cases.**

   The five controlled drainage projects resulted in a net increase in the acreage available for crop production at the sites. Some projects also resulted in such agronomic benefits as improved field efficiency and timing, reduced input costs, increased yields, increased livestock carrying capacity, reduced risk of water shortages, or increased cropping options. The actual benefits were, in some cases, much less than the benefits expected by the cooperating producers. For example, surface ditches remained wet and impeded field operations in some projects.

5. **None of the six projects were viable from a farm financial perspective.**

   The farm financial evaluations compared on-farm costs with on-farm benefits. The Benefit/Cost ratios ranged from about 0.2 to 0.5. Even with the actual government cost-sharing for these projects, which ranged from 55% to over 75% of the total project costs, only the Massey project approached financial viability. Almost no government assistance is now available for such projects.

   The financial analysis included the following sensitivities: ±20% changes in total annual revenue projections, increased crop yields and/or crop quality in the drained depressions, revised construction costs based on design changes, changes in farm efficiencies, and a lowering of the discount rate from 10% to 5%. In these sensitivity tests, only the Massey project came close to the breakeven point (assuming that crop yields from the drained depressions were equal to upland crop yields).

   The financial results reinforce the contention that non-financial factors also influence producers' water management decisions. For many producers, practical factors which make their lands easier to farm, such as field efficiency, trafficability and timing, are key objectives for their water management systems even if these factors are not very significant from a financial perspective.

6. **None of the six projects were viable from a socio-economic perspective.**

   The socio-economic assessments compared on- and off-farm costs with on- and off-farm benefits. They reflect the economic value of the projects to society. The low Benefit/Cost ratios reflect the high costs of mitigating on-farm habitat loss and downstream erosion and flooding. Without the control structures used in the five controlled drainage projects, the negative off-farm effects would have been significantly greater.

7. **Slough consolidation with limited waterfowl habitat mitigation resulted in significant losses in wetland habitat and waterfowl productivity. Effective waterfowl habitat will decrease up to 90% if this technique is carried out on large blocks of land.**

   This study tested the effects of consolidation of temporary wetlands combined with waterfowl habitat mitigation of the consolidation pond and very limited upland habitat mitigation. The impact of this technique on waterfowl productivity is strongly negative for the drained quarter. For example, the estimated loss of habitat for the Massey quarter averaged 91% for two representative dabbling duck species (Gadwall and Blue-winged Teal) and 81% for a diving duck species (Canvasback).

   In addition to reducing waterfowl productivity, the loss of wetland habitat will harm many other species of birds, mammals, amphibians, reptiles and plants which depend on wetlands for all or part of their life cycle.

8. **The results from the Massey project highlight the need to resolve conflicting resource management goals and indicate that finding acceptable compromises will not be easy.**

   This project showed that slough consolidation using subsurface tubing with Jensen inlets is technically feasible and may be financially viable on knob and kettle topography if crop yields from the drained depressional areas are equal to upland yields. This creates a serious concern because knob and kettle topography provides prime waterfowl habitat mainly due to the many wetlands. On one hand, governments and the private sector are working to restore waterfowl populations; on the other hand, greater stability in agriculture, increased demand for a more secure water supply for livestock production, or higher commodity prices could prompt more producers to implement water management systems similar to the Massey project.

> The problem of competing land uses needs to be addressed to find a middle ground that will enable Alberta to sustain both environmental resources and agriculture.
>
> Finding a middle ground will be difficult. Although many producers value wildlife, some view it as little more than a nuisance. Furthermore, even those producers willing to actively encourage wildlife may consider wetland consolidation with limited habitat mitigation as a reasonable compromise between the needs of agriculture and wildlife. For wildlife populations, this "compromise" would be very detrimental.

Major Conclusion

While various alternatives to uncontrolled drainage were found to satisfy one or more resource management objectives, no measures were found that would sustain agriculture and the soil, water and wildlife resources over the long term.

The controlled water management systems provided some agronomic benefits and protected downstream areas from increased erosion, flooding and sedimentation. However, the systems were not financially or economically viable and did not maintain wildlife populations.

Although these systems could be refined to increase the benefits and reduce habitat loss, the improvements would not be sufficient to achieve sustainability on a quarter section basis. That is, the use of controlled drainage, by itself, will not sustain agriculture and the environment over the long term.

Despite the disadvantages of drainage, agricultural producers will likely continue to want to drain because of the potential agronomic advantages such as reduced crop losses, improved trafficability and timing of field operations, increased acreage under cultivation, increased crop choices and yields, and reduced input costs. Furthermore, most producers will likely prefer uncontrolled drainage because of the low farm costs for construction.

The Challenge

The study's major conclusion points out the challenge facing Albertans of how to guide farm water management practices towards agricultural and environmental sustainability. Meeting this challenge is important in all areas of Alberta and crucial in knob and kettle terrain.

The On-Farm Water Management Study Steering Committee believes we can meet this challenge through two main approaches. Improved goal setting and planning needs to occur at the provincial, municipal/sub-basin, and farm levels. As well, government resources and programs should support sustainable resource management.

This challenge is one of many we face in creating a sustainable future. We can build such a future by working together and by developing a common goal towards stewardship of our resources.

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Appendix A

Glossary of Terms

Backflooding: Confining or slowing down the gravity drainage of water such that the water is temporarily impounded.

Benefit/Cost Ratio (B/C Ratio): The ratio of benefits to costs. For this study, the benefits are the discounted incremental net benefits and the costs are the discounted total investment costs. The breakeven value is B/C = 1.

Berm: A low mound of earth constructed to impound the flow of water.

Breeding Pair Densities: The estimated number of breeding waterfowl pairs per hectare of wetland.

Brood Densities: The estimated number of waterfowl broods (hen and her young) per hectare of wetland.

Choke: A device used to control surface drainage runoff rates by temporarily impounding water when runoff rates exceed the capacity of the device.

Consolidation Pond: A water storage facility provided to collect and retain runoff water from areas drained to permit agricultural development.

Contributing Watershed Area: That portion of a watershed which contributes to surface runoff during a specific rainfall or snowmelt event.

Crest Gauge: A device, usually attached to a staff gauge (see **Staff Gauge**), to leave an indicating line marking the highest water level reached over a period of time between manual observations.

Curve Number (CN): Values from 0 to 100 as developed by the U.S. Soil Conservation Service where: CN = 1,000/(10 + S) and S is the maximum potential difference (storage) between the storm rainfall depth and the direct runoff depth in inches that could occur for the given storm and watershed conditions. Relations developed give a total runoff depth for any selected CN value for a given total storm precipitation depth.

Dabbling Ducks: Ducks which feed in shallow waters on plants and insects just under the water surface and along the edges of lakes, ponds and smaller bodies of water. They nest in upland areas. Some examples of dabbling ducks are: Mallard, Blue-winged Teal, Green-winged Teal and Gadwall.

Dark Gray Luvisol: A leached/degraded soil midway in quality between a high quality tall grass prairie soil (i.e., a Black Chernozem) and a lower quality aspen forest soil.

Depressional Area: A low lying area subject to ponding for periods long enough to make it agriculturally non-productive.

Design Capacity: The maximum discharge which a control device is designed to convey.

Discount Rate: The rate at which revenue received in the future is discounted (reduced) to account for the fact that revenue received today is worth more than revenue received in the future.

Discharge: The volume of flow per unit time.

Diving Ducks: Ducks which feed by diving to the bottom of deeper water bodies and foraging for plants and animals.They are generally frequenters of large inland water bodies. They often nest on or near the water in emergent vegetation. Some examples of diving ducks are: Canvasback, Lesser Scaup and Redhead.

Ephemeral Wetland: A wetland which is present for brief periods during the growing season, usually in early spring (Stewart and Kantrud, 1971).

Farm Conservation Planning: A process of documenting the soil and water resources on a farm, examining current farming practices and other options, and then selecting the most appropriate and sustainable practices.

Farm Financial Evaluation: A comparison of on-farm costs versus on-farm benefits of a proposed project, all measured in terms of prices which may include taxes and subsidies. An on-farm cash-flow analysis.

Flume: A water conveyance device used to measure a wide range of discharges.

Full Supply Level: The maximum desirable operating level of a water storage facility. A means of spilling is usually provided if this level is exceeded.

Gabion: A permeable rock-filled wire basket used for erosion protection and slope stabilization.

Gleysolic Soil: A soil formed where the water table is near the surface for a portion of the year.

Gross Watershed Area: Of a waterbody or stream at a specified location, is the area which would contribute runoff to that location under extremely wet conditions.

Habitat Suitability Index (HSI): Developed by the U.S. Fish and Wildlife Service, a habitat index ranging from 0.0 to 1.0 based on assessments of physical and biological characteristics of the habitat for a selected species. High HSI values indicate good habitat quality, and low HSI values are indicative of poor habitats.

Habitat Unit (HU): The functional value of a particular wetland to a designated wildlife species, calculated by multiplying the Habitat Suitability Index (HSI) value of the wetland by the wetland's surface area. For example, a 2 ha wetland with an HSI rating of 0.4 would represent 0.8 HU, whereas a 1 ha wetland with an HSI rating of 1.0 would represent 1.0 HU.

Humic Luvic Gleysol: A gleysolic soil that has an accumulation of organic matter over an eluviated or leached layer. The accumulation of organic material is from grasses and forbs. The ashy coloured leached layer indicates significant downward movement of water.

Incised Channel: A stream which has cut into the ground surface and as a result is usually confined during high flows.

Indicated Breeding Pair (IBP): Estimated number of breeding waterfowl pairs present on a waterbody during the "optimal breeding period" for a specific species. At the optimal breeding period, migrants and non-breeding pairs should have departed. The remaining pairs reflect the true breeding population.

Infiltration: The flow of water into the soil by gravity.

Internal Rate of Return (IRR): Represents the average earning power of money used in a project over its lifetime. The IRR is the discount rate which just makes the net present worth of the cash flow from the project equal to zero. It is the rate at which the present worth of benefits equals the present worth of the costs.

Jensen Inlet: An inlet used to drain water from depressional areas into a subsurface drainage system. It protrudes above the ground surface and is connected to the subsurface tubing. The inlet consists of a slotted portion of polyvinyl chloride (PVC) pipe and has a sleeve which when lowered over the slots allows ponding until the sleeve is raised.

Knob and Kettle Topography: Glacially deposited sediments characterized by an irregular arrangement of mounds (knobs) and depressions (kettles); also called hummocky moraine.

Knoll: A small rounded hill; a knob.

Mini-slab Erosion Protection: Prefabricated interlocking concrete blocks laid across a channel bed and banks to minimize potential water erosion.

Nesting Islands: Islands within wetlands that waterfowl use for nesting. These islands usually provide maximal protection from terrestrial predators; hence, birds nesting on islands have a greater chance of nest success than those nesting in uplands adjacent to wetlands.

Net Present Value (NPV): The net value or net benefit of a project when all costs have been discounted to the present using the appropriate interest rate. The NPV may be positive or negative. It is zero at the breakeven point, and positive when benefits are greater than costs.

Orthic Dark Gray Chernozemic Soil: A soil developed under forest-grassland transition zones, having a larger proportion of grasses to aspen than a Dark Gray Luvisol.

Orthic Gleysolic Soil: A "normal" gleysolic soil.

Orthic Humic Gleysol: A gleysolic soil with a thick organic surface layer.

Permanent Wetland: A wetland where water covers the land surface throughout the year in all years (Stewart and Kantrud, 1971).

Rego Black Chernozemic Soils: A very new or eroded grassland soil (i.e., a black soil with poor horizon development).

Resting Islands: Islands within a wetland that waterfowl use as an area to rest and preen their feathers. These islands are attractive to waterfowl because they provide maximal protection from terrestrial predators.

Return Period: An indication of how often an event will occur. For example, a 1 in 100 year return period event has a 1% probability of occurring in any given year and over the long term would occur on average once every 100 years; a 1 in 20 year event has a 5% probability of occurring in any given year.

Runoff: Runoff is that part of the precipitation received at the ground surface which does not infiltrate the soil or return to the air through evaporation but instead flows over the ground surface and collects in depressions, streams and lakes.

Scat: Animal fecal dropping.

SCS Procedure: The method developed by the U.S. Soil Conservation Service for estimating rainfall runoff from soil and cover data as published in SCS National Engineering Handbook, Section 4, "Hydrology Part I - Watershed Planning", August, 1964.

Seasonal Wetland: A wetland which contains water for extended periods, especially early in the growing season, but has no water by the end of the growing season (Stewart and Kantrud, 1971).

Semi-Permanent Wetland: A wetland which usually retains water through the growing season (Stewart and Kantrud, 1971).

Side Slope: The slope of the banks of a ditch or channel.

Slope, Channel: The change in height divided by the distance from one point to another along a channel; also called gradient.

Slough Consolidation: Draining several small wetland areas and storing the drained water in a single, larger wetland area.

Snowcourse: Average depth of snow, usually expressed as a water equivalent depth in millimetres, lying on the surface of the ground.

Socio-Economic Assessment: A comparison of on- and off-farm costs versus on- and off-farm benefits of a proposed project, all measured in terms of accounting (or "shadow") prices which reflect the economic value of the inputs and outputs to society at a provicial scale. It eliminates market price distortions (i.e., taxes and subsidies), values all non-marketable commodities and ignores who pays and who benefits, i.e., it captures the cost or benefit of impacts both internal and external to the farm boundaries in question.

Spillway Channel: A channel used to convey excess water when flows and/or water levels exceed a specific point. Usually used to protect a structure from being overtopped.

Staff Gauge: A graduated device placed in a water conveyance or storage facility to manually measure the water level. The elevation of the gauge is usually surveyed to a fixed reference point.

Stoplog: A removable barrier designed to fit across a water conveyance opening to block flow of the water.

Study Watershed: The area which might be expected to entirely contribute runoff to a specific flow monitoring point under extremely wet conditions (see **Gross Watershed Area**).

Subsurface Drainage: Gravity drainage of depression areas using Jensen Inlets connected to subsurface tubing which drains to a sump pump.

Subsurface Tubing: Flexible pipe installed below ground to convey drainage water.

Supplemental Irrigation: Minor additional irrigation to increase moisture conditions on a normally non- irrigated farm operation.

Surcharge: To pump water into a reservoir so as to raise its level above the maximum possible by gravity inflow.

Sustainable Management; Sustainability: Referring to practices which meet current needs without compromising the ability of future generations to meet their own needs.

Swale: A low slope, conventional field ditch.

Temporary Wetland: A wetland which is present for brief periods during the growing season (Stewart and Kantrud, 1971).

Terric Mesisol: An organic soil which is saturated for much of the year; the upper half of its profile is made up of partially decomposed organic matter. A peat soil.

Transitional Area: The area between a depression and an upland, occasionally subject to ponding especially during spring snowmelt and high magnitude rainfall events. This area may have lower crop production due to weed infestation and poorer soil conditions.

Uncontrolled Drainage: Surface drainage of runoff water using gravity draining ditches without any obstructions to flow other than the capacity of the ditch and the surrounding land.

Upland: An agriculturally productive area not subject to ponding.

Appendix B

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